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OF
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The Authors of Papers are alone responsible for the statements
and
the opinions expressed therein.

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THE ROYAL SOCIETY OF WESTERN AUSTRALIA, INC.

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VOLUME XXV.

The Royal Society of Western Australia (Inc.).

ANNUAL REPORT OF COUNCIL FOR THE YEAR ENDED 30TH JUNE, 1939.

Ladies and Gentlemen,

Your Council begs to submit the following report for the year ended 30th June, 1939.

Council.—The Council of the Royal Society met on four occasions, and the Executive Committee on five occasions.

On account of the large amount of routine business to be considered at meetings, an Executive Committee consisting of the President, Senior Vice-President, Hon. Treasurer, the Hon. Council Secretary, the Hon. Meeting Secretary, Hon. Librarian and Hon. Editor was appointed to deal with such matters and report to the Council which would meet quarterly. This appointment has proved a very satisfactory departure.

Finance.—The General Fund shows a balance of £96 8s. 5d. Against this there are commitments to the Government Printer of approximately £60. The Endowment Fund has been increased by £25 and now amounts to £275. The grant of £100 from the State Government has been continued and is gratefully acknowledged, as without this financial assistance it would be impossible to publish the Journal in its present form.

The satisfactory condition of the Society's finances reflects the careful management of the Hon. Treasurer, Dr. Watson.

Membership.—There has been a slight decrease in membership during the year. Seven Ordinary Members and three Associate Members have resigned and only five Ordinary Members and two External Members have been elected to the Society.

It is reported with regret that the Society has lost three members by death—Mr. W. D. Campbell, Mr. H. Gloe and Mr. L. J. Newman, late Government Entomologist. Mr. Newman was a Foundation Member of the Society and did valuable work in the promotion of the affairs of the Society.

There are at present 156 members of the Society made up as follows:—

Honorary Members	7
Corresponding Members	7
Ordinary Members	91
Associate Members	46
Student Members	5

Lectures.—During the year five important lectures covering a wide field of scientific interest were delivered to members of the Society. These were:—

"Red-legged Earth Mite" by Mr. R. Norris.

"Some Impressions of Museums Abroad" by Mr. L. Glauert.

"Impressions of University Education and Research Abroad" by Dr. E. J. Underwood.

"Producer Gas and its application to Australia's Fuel Problem" by Professor A. T. Bowden.

"Royal Botanic Gardens, Kew" by Mr. C. A. Gardner.

Short discussions on the geological, paleontological and pedological aspects observed in the Gingin area, were also given by members who had taken part in the October excursion.

Mr. L. Glauert and Miss E. A. Bowley presented a film depicting a honey mouse with five of its offspring.

In addition to the formal programmes a number of interesting exhibits, principally botanical and geological specimens, were tabled and described for the information of members.

Excursions.—One excursion was arranged during the year under the leadership of Dr. E. S. Simpson and Dr. L. J. H. Teakle. Members and friends visited Gingin on 8th October, 1938, and spent a very interesting and profitable day studying geological, physiographic. and soil features which are well illustrated. A number of minerals were observed in various geological horizons and members searched for fossils in appropriate beds.

Journal.—The publication of Volume 24 has been completed and the Journal distributed among members and scientific institutions with which the Society is in exchange.

During the year eleven papers were presented to the Society for publication in the Journal. These covered a wide range of topics and represented contributions to our knowledge of Western Australia.

The thanks of the Society are due to the Government Printer and his staff for the wholehearted co-operation which has been accorded to the Hon. Editor, Mr. B. L. Southern.

Acknowledgment is also made of the services of Mr. Southern who remains in the office of Hon. Editor and makes available his experience in this work to the great advantage of the Society.

Library.—The Society has entered into exchange of publications with a total of 174 scientific institutions of which 53 are in Australia, 16 in the United Kingdom, 21 in other parts of the British Empire, 43 in North and South America, 38 on the Continent of Europe and 3 in Asia.

This year new exchanges have been entered into with scientific bodies in New South Wales, Queensland, Sweden, Holland and Brazil.

These exchanges are enabling the Society to build up a library of very considerable value to those interested in science in Western Australia. In order to facilitate the use of these publications, an active programme of binding has been organised and this year some 114 volumes have been bound.

The thanks of the Society are due to Mr. L. Glauert and Miss E. A. Bowley for the work put into the Society's library so that the information may be available to members when required.

Photograph of His Majesty the King.—The Society was privileged in receiving an autographed photograph of His Majesty King George VI. It was unveiled in the Society's Rooms on 14th March, 1939.

EDWARD S. SIMPSON,
President.

L. J. H. TEAKLE,
H. N. JAMES,
Joint Hon. Secretaries.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA, INCORPORATED.

Statement of Receipts and Expenditure for the Year ended 30th June, 1939.

Receipts.

	£ s. d.
General Fund—	
Balance at 1st July, 1938	85 0 3
Interest, 1937-38	2 13 7
Subscriptions	110 10 6
Government Grant	100 0 0
Authors' Reprints and Half Cost of Blocks	16 1 8
Interest on Fixed Deposit	7 10 0
	£321 16 0

Expenditure.

	£ s. d.	£ s. d.
Petty Expenses, including Postages, etc.		12 15 3
Clerical Assistance		7 15 3
Museum Trustees—Rent and Attendance		16 1 0
G.P.O. Box Rent		3 0 0
Annual Meeting—Rent	2 9 4	
,, ,, Catering	3 19 0	
		6 8 4
Ordinary Meetings—Catering		9 0 0
Library—Bookbinding	29 13 0	
,, Cases	0 7 6	
		30 0 6
Transfer to Medal Fund		2 10 0
Transfer to Endowment Fund		25 0 0
Government Printer—Vol. XXIV., completing	65 19 8	
,, ,, Miscellaneous Printing	5 8 0	
		71 7 8
Cost of Preparation of Blocks		7 8 3
Editor's Honorarium		15 15 0
Subscription to Aust. Journ. of Science		0 12 0
Replica of Kelvin Medal (Mrs. Hancock)		0 12 6
Portrait of H.M. King George VI.		6 0 4
Sir John Russell Lecture—Expenses		4 9 0
Stationery Cabinet		6 12 6
Balance at 30th June, 1939		96 8 5
		£321 16 0

Receipts	£ s. d.	Expenditure	£ s. d.
Medal Fund—			
Balance at 1st July, 1938	16 18 3		
Interest, 1937–38	0 7 11		
Transfer from General Fund	2 10 0	Balance at 30th June, 1939	19 16 2
	£19 16 2		£19 16 2

Receipts	£ s. d.	Expenditure	£ s. d.
Endowment Fund—			
Balance at 1st July, 1938	250 0 0		
Transfer from General Fund	25 0 0	Balance at 30th June, 1939	275 0 0
	£275 0 0		£275 0 0

Note.—£250 placed on fixed deposit at Commonwealth Bank, Perth, on 13th June, 1938, for 24 months, bearing interest at 3% per annum. £25 placed on fixed deposit at Commonwealth Bank, Perth, on 30th June, 1939, for 24 months, bearing interest at 3% per annum.

Summary of Funds at 30th June, 1939.

	£ s. d.
Credit Balance, General Fund	96 8 5
,, ,, Medal Fund	19 16 2
,, ,, Endowment Fund	275 0 0
	£391 4 7

1st July, 1939. E. M. WATSON, Hon. Treasurer.

Audited and found in agreement with books, receipts and vouchers produced and we consider this a true statement of the Royal Society's Accounts.

R. E. GATHERER,
H. P. ROWLEDGE,
Hon. Auditors.

ABSTRACT OF PROCEEDINGS, 1938-1939.

12TH JULY, 1938—

Annual General Meeting held in Gledden Hall. Presidential Address: "A Regional Classification of the Soils of Western Australia" by Dr. L. J. H. Teakle.

9TH AUGUST, 1938—

Papers—"Simpsonite, a new Tantalum Mineral from Tabba Tabba, Western Australia," Mr. H. Bowley.

"X-Ray Studies of the Structure of Simpsonite," Miss L. E. Taylor; communicated by Mr. J. Shearer.

Lecture—"The Red-legged Earth Mite," Mr. R. Norris.

13TH SEPTEMBER, 1938—

Papers—"The Devonian Nautiloid Cephalopods from Western Australia," Dr. C. Teichert.

"A Second Australite Observed to Fall in Western Australia," Dr. E. S. Simpson.

"A Review of the Land Mollusca of Western Australia," Tom Iredale; communicated by Mr. L. Glauert.

11TH OCTOBER, 1938—

Exhibit Night—The evening was devoted to talks on exhibits collected during an excursion to Gingin on 8th October.

8TH NOVEMBER, 1938—

Address—"Some Impressions of Museums Abroad," Mr. L. Glauert.

13TH DECEMBER, 1938—

Papers—"Jurassic Ammonites from Western Australia," Dr. C. Teichert.
"Life History of Macrozamia Reidlei," Miss A. M. Baird.

Dr. Prider described a method of photographing rock surfaces.

14TH MARCH, 1939—

Paper—"Western Australian Devonian Corals in the Wade Collection," Dr. D. Hill; communicated by Dr. Teichert.

Address—"Impression of University Education and Research Abroad," Dr. E. J. Underwood.

18TH APRIL, 1939—

Papers—"The Donnybrook Sandstone and its place in the Stratigraphical Sequence," Mr. A. Gibb Maitland.

"Carminite and Bindheimite from the Ashburton Valley," Mr. C. R. Le Mesurier.

9TH MAY, 1939—

Address—"Producer Gas and its application to Australia's Fuel Problems," Associate Professor Bowden.

13TH JUNE, 1939—

Paper—"Contributions to the Fauna of Rottnest Island—No. 10: Pycnogonida of Western Australia" by Mr. G. Williams; communicated by Mr. Glauert.

Address—"Royal Botanic Gardens, Kew," Mr. C. A. Gardner.

Exhibits—Pouched honey mouse and five offspring—Mr. Glauert and Miss E. A. Bowley.

Caranx ferdau—A fish new to Australian waters and caught outside Fremantle—Mr. Glauert.

INSTRUCTIONS TO AUTHORS.

1. All matter for publication must be typed, written on one side of the paper only and *double-spaced* to permit corrections and printer's directions. A margin of at least one and a half inches must be allowed at the left hand side.

2. (*a*) References to literature should be given in a list at the end of the paper and indicated in the text by an index number in parentheses, thus—(5).

(*b*) Order as appearing in text, in case of repetition the original number is to be referred to.

(*c*) Author's name.

(*d*) Name of article, only if necessary, or book.

(*e*) Name of publication in italics.

(*f*) Year.

(*g*) Volume—in Latin type, part if necessary in ordinary type in square brackets [3].

(*h*) Page.

Example :—

(5.) Smith, A.B., *Jour. Roy. Soc. W. Aust.*, 1920, **9** [2], p. 8.

3. Abbreviated titles of publications are to be in agreement with those given in the *World List of Periodicals*. Authors not familiar with this list should give titles in full.

4. Authors are required to pay one half the cost of preparation of blocks for illustrations.

5. Thirty reprints are allowed to authors or joint authors between them. Extra reprints may be purchased by arrangement with the editor provided the number required is indicated on the manuscript.

JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

VOLUME XXV.

1.—A REVIEW OF THE LAND MOLLUSCA OF WESTERN AUSTRALIA.*

By TOM IREDALE,
Conchologist, The Australian Museum, Sydney, New South Wales.

By Permission of the Trustees of the Australian Museum.

Read 13th September, 1938; Published 21st August, 1939.

Forty odd years ago E. A. Smith of the British Museum published an account of the land shells of Western Australia, and since then numerous additions are available for record, and the present essay brings our statistical knowledge down to date. Twenty years ago Hedley listed the species, then known, in his Preliminary Index but no detailed revision was attempted. It must be emphasised that this review is intended to serve as a basis for Western Australian workers, and consequently most attention has been paid to the taxonomy and discrimination of the named forms. It is important in this group to know the topography, geography, geology and botany, a combination I have termed Geozoology, of the State to define exactly the status of the molluscs collected, all these factors being of definite influence in the evolution of the mollusc. It may be pointed out that in over one hundred years of history of the State no local naturalist has made any major contribution to our knowledge of this group though probably no more profitable group could be selected, the problems being innumerable and all of them interesting. Smith noted "The report is limited to those species occurring west of long. 129°E., the boundary line between West Australia and South Australian territory. Its extreme length from north to south is 1,250 miles and 800 from east to west, and it embraces an area of 1,000,000 square miles." The limits given are those of Western Australia, as politically known, but the area does not agree with that provided by the W.A. Government, which in the Year Book before me reads 975.920 square miles. I have indicated the natural divisions of Australia as shown by the Land Mollusca, and it will be seen from the map here reproduced that within the unnatural political boundaries of Western Australia three faunulae are represented, two restricted and one intrusive element. The Autochthonian Faunula restricted to the south-west corner, termed the Leeuwinian Area, is characterised by the very peculiar Bothriembryontid development. With it are a few Endodontids, the only Helicarionid west of Victoria, and a (perhaps) Rhytidid, no Helicids save through intrusion. On the other hand the north-west part of Australia, called the Dampierian Sub-Area, is inhabited by a Caurine Faunula which is of very peculiar facies related to the molluscan fauna of

* Portion of the cost of printing this paper has been borne by the Trustees of the Western Australian Museum and Art Gallery.

the East Indies rather than with that of the adjacent territories. These are peculiar Helicids, and no Bothriembryontids occur save as stragglers into the southern point. There is no *Helicarion* and no Rhytidid while the so-called Chloritids are peculiar, and two Microcystids occur. These two faunulae are very peculiar in their composition, and the third is that of the Centralian Area, known as the Eremian or Eyrean Faunula, an intrusive series. This faunula ranges across the whole of the centre of Australia and runs into the south-west, meeting members of the Autochthonian Faunula. It further reaches the coast to the north of the Leeuwinian Area, but so far it has not been recognised in connection with the Caurine Faunula. This inland area of Western Australia has not been explored for molluscs so that probably many species exist. While these may be related to the known members of the Eremian Faunula it is possible that the novelties may offer shells of different form.

Possibly the vegetation will offer most assistance and in this respect "The Soils of Australia in relation to Vegetation and Climate" (Commonwealth C.S.I.R. Bulletin No. 52, 1931) by Prescott is worthy of intensive study. Examination of the vegetation map therein included suggests that the groups of Bothriembryontid molluscs are distributed in accordance with the botanical data.

The following account as to the rainfall, the most important item in the life history of a snail, is taken from an official source. The rainfall varies throughout the South-West division, ranging from an annual average of 50 inches in the heavily timbered portions of the coastal districts to 18 inches at Geraldton and nearly 10 inches at Yalgoo, from 36 inches at Albany to 14 inches at Israelite Bay, and from 44 inches in the Darling Ranges to 21 at Toodyay, 16 at Northam, and 10 at Southern Cross. A similar diminution occurs eastward of Bunbury, starting with a register of 37 inches. The climatic conditions are vastly different in the tropical parts of Western Australia. Heavy tropical rains fall from the end of November to the end of March, with rarely a wet day during the rest of the year. For instance the average at Wyndham is nearly 27 inches of which 24½ fall in November to March, another 1½ in October and April, the total from May to September inclusive being less than 1 inch. On the other hand that of Perth is only 34 inches, December, January, February averaging nearly ½-inch each month, April and May nearly 1 inch each while May, June, July and August have from 5 to 7 inches each month. The rainfall at Albany is a little lighter in the winter months, but a little heavier in the summer, totalling a little more than 39 inches in the year. In this connection it may be recorded that apparently most Western Australian snails develop a strong epiphragm for use during the long dry spells.

I have long hoped to provide a ground work for students of Australian land-shells as these are very abundant, varied in form and scientifically very valuable. To this end I have published A Basic List of the Land Mollusca of Australia in the Australian Zoologist (Vol. VIII., pp. 287-334, Mch 12, 1937; Vol. IX., pp. 1-39, pls. I.-III., Nov. 12, 1937; and Vol. IX., pp. 83-124, pls. XII.-XIII., Nov 30, 1938). I later prepared "An Annotated Check List of the Land Shells of South and Central Australia" which has appeared in the South Australian Naturalist (Vol. XVIII., pp. 6-57, pls. I.-II., September 30, 1937). The present essay leaves Queensland and New South Wales to be as completely treated, and these I have in hand now. No section, however, provides the delightful complications present in the Western Australian

Fauna and I have to thank sincerely Mr. L. Glauert for the opportunity of examining so much material.

My thanks are also here tendered to my colleagues, Miss Joyce Allan, who has prepared the excellent drawings which accompany this report, and Mr. G. C. Clutton for the photographs of the Bothriembryontid forms.

I.—HISTORICAL ACCOUNT.

While it be possible that some of the earlier visitors such as Vlaming, Pelsart, Dampier or Vancouver may have carried back landshells to Europe, the first real note was made by Peron in 1807 who recorded that on June 29, 1801, at Bernier Island, also Dorre and Dirk Hartog's Islands, in Shark Bay, "Two species of landshells extremely numerous, but all dead, occupied great stretches of the interior of the island, one was a small species of *Helix,* the other belonged to the genus *Bulimus* of M. de Lamarck."

Thus from this source Ferussac included in his Prodrome *Helix costulata, H. melones* and *H. torulus.* The former was not described and figured but localised as "Le port du Roi George, Péron: la baie des Chiens-Marins, Gaudicho," the second as "La Nouvelle-Hollande," the last as "La Nouv.-Hollande, voyage de Péron." It will be noted that another collector Gaudicho (Gaudichaud) is here mentioned. C. Gaudichaud was apothecary on the Uranie, on which vessel Quoy and Gaimard were the naturalists: this vessel visited Shark Bay September 12-27, 1818, and was shipwrecked at the Falkland Islands on its way home and the collections made lost; but apparently Gaudichaud managed to save some of his treasures. Lamarck published with a description in 1822 *Bulimus inflatus* citing as synonymous Ferussac's *H. costulata.* Another species named and figured by Ferussac, *Helix prunum,* and whose locality was given as "Les Terres Australes, voyage de Péron" has been credited to Western Australia, but examination of the figure suggests an Eastern Australian form. Then the English explorer Captain P. P. King, who was very interested in natural history, collected land-shells at King George's Sound on January 20, 1818. Gray, of the British Museum, described a species naming it after King in 1825, King's own account not being published until 1826. In the latter year the "Astrolabe" another French exploring vessel, was in Western Australian waters, and the brilliant and enthusiastic naturalists Quoy and Gaimard were on board, intent to make up for their losses in the Uranie shipwreck. The land-shells secured were this time safely taken to Paris and were carefully described and beautifully illustrated in one of the most splendid works on natural history yet issued.

An unknown collector, probably Robert Brown, provided Gray of the British Museum with some material, and it has only recently been recognised as coming from the Recherche Group. A little later a German collector, Dr. L. Preiss, visited South-West Australia in 1839-40, and Menke issued an account of the mollusca in 1843. At the same time Gilbert, the famous ornithological assistant of Gould, secured some shells and these were transferred to the British Museum by Gould, and have been regarded as having been collected by that gentleman, who, however, never reached Western Australia during his famous travels. Simultaneously Captain Stokes was exploring the West Coast and he and his men were notable collectors, Dring, Wickham and Ince all coming under notice in connection with land-shells. Unfortunately the exact localities were not preserved by those to whom the shells passed and thus in some cases it has been a matter of great difficulty in determining these at the present time. It must be remembered that this was the day of sailing vessels which called in and sheltered at places not now commonly resorted

to, but when intensive collecting is carried out it may become easy to fix the exact place as the species are comparatively well defined.

When Eyre crossed from South to West Australia he noted shells scattered about on the ground but that does not concern us as none appears to have been collected. It must be recalled that he was succoured by Captain Rossiter of the French whaler Mississippi on June 2, 1841. That particular captain happened to be a very zealous amateur conchologist, and later settled in Sydney, when the well-known professional conchologist John Brazier married his sister. Later Brazier circulated shells collected by his brother-in-law, who had secured them on the islands of the Recherche Archipelago when whaling about them.

Until this date all the species had been described in Europe, and a few collected by Dr. Bacon in the Swan River Settlement were named by Benson, but now Australian conchologists became qualified, and Cox, Hedley, Angas, Brazier, Tate and Hedley have all made additions to our knowledge. Still the spell of the extralimital worker held, although he was ignorant of local conditions and heedless of geography and history. Thus E. A. Smith in the Zoology of the Voyage of the Erebus and Terror dealt with two plates (that had been prepared for Stokes) under the impression that they had something to do with that voyage. Fortunately the species figured were so distinct that he could not make many mistakes, but he managed to confuse matters a little. Smith, however, assisted our study, when he prepared the first complete account of Western Australian land-shells based upon a collection made by the well-known entomologist, J. J. Walker,* when he was chief engineer on H.M.S. Penguin, surveying off the North-West coast of Australia. It is unfortunate for Australian students that Walker's collection was made on almost inaccessible islands, but his discoveries opened a new vista for the forms were of novel facies and now provide the most intriguing problem in our science.

W. W. Froggatt, a professional entomological collector, went to Derby and explored the Napier and Oscar Ranges, and brought back some twenty species of land and fresh-water molluscs. Some of these were described by Cox and others by the great French conchologist Ancey, but no complete study of the collection was attempted. The bulk went into the Macleay Museum and has been here utilised. Years later Dr. Herbert Basedow went into the Napier Ranges, and an excellent collection was briefly recorded by Hedley. The dominant Western Australian group, *Bothriembryon,* was carefully monographed by Pilsbry, who had much material sent him for the purpose by Cox, but the localities provided by the latter were untrustworthy and misleading. Kobelt, a year later, also catalogued the group, practically following Pilsbry. Some odd species have been named by Fulton, Preston, Gude, Odhner and Thiele. The two latter dealt with collections made by Swedish expeditions to the North-West, and German expeditions to the South-West, respectively.

Mr. Sidney W. Jackson visited Western Australia in 1912, and working in the Bow River district, south coast, made a fine collection which was accompanied by excellent field notes. This series included many novelties and was examined by Hedley but the results were never published. About ten species were secured, all of them new, and suggest great possibilities to some local enthusiast.

The only recent collectors have been Mr. L. Glauert, the Director of the Museum, to whom I am greatly indebted for the opportunity of studying the material in that Museum, upon which this review is primarily based; Mr. F. R. Bradshaw, of Tambellup, and Mr. E. Sedgwick, of Nangeenan, each of whom have sent me very interesting shells.

* Died February, 1939.

It is my great hope that this account will arouse someone in Western Australia to study their own molluscan fauna, which suggests more problems than almost any other in the world. Prior to Smith in 1894 some thirty-five species had been recorded: in his essay Smith added eighteen, that is half as many again. Hedley listed the fauna in 1915 as eighty, that is almost exactly half as many again. This list has increased the number in a similar proportion, and yet I conclude that the number on record is only a small proportion of the molluscs living. A representative collection will be made available at the Perth Museum for students, and I will be only too pleased to assist any such in any way that I possibly can.

PHYLUM MOLLUSCA.

Class GASTROPODA.

Subclass PROSOBRANCHIA.

Order PECTINIBRANCHIA.

FAMILY **HELICINIDAE.**

Small conical operculates, solid, spire short, whorls flattened, periphery subkeeled, umbilical area covered by a callus pad.

Genus **PLEUROPOMA** Möllendorff 1893.

1893—*Pleuropoma* Möllendorff, Ber. Senckenb. Nat. Ges. Frankfürt, 1893, p. 140, July. Orthotype *Helicina dichroa* Möllendorff.

1905—*Aphanoconia* Wagner, Denksch. K. Akad. Wissen. Wien, Math. Nat. Class., Vol. LXXVII., p. 388. Logotype Iredale, Austr. Zool., Vol. VIII., p. 291, 1937, *Helicina verecunda* Gould.

1905—*Reticulata, Sculpta, Dichroa* id ib., sectional names only with Tautotypes.

1909—*Albocincta* Wagner, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. 18, heft ccxxv., lief 535, p. 169. Tautotype *Helicina albocincta* Hombron & Jacquinot.

1909—*Sphaeroconia* id. ib., heft ccxxviii., lief 538, p. 189. Logotype Iredale, Austr. Zool., Vol. VIII., p. 292, 1937, *Helicina sphaeroconus* Möllendorff.

Pleuropoma walkeri Smith 1894.

Plate I., fig. I.

1894—*Helicina walkeri* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 99, pl. VII., fig. 26, June. Queen's, Baudin and Parry Islands, North-West Australia.

1909—*Aphanoconia* (*Sphaeroconia*) *baudinensis* Wagner, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XVIII., p. 217, pl. 43, figs. 11-13, as of Smith *errore,* new name for *walkeri* Smith. Baudin Island, N.W.A.

Shell small, depressedly conical, spire short, whorls flattened, last whorl subkeeled, mouth lunate, outer lip slightly thickened, umbilical area covered by a callus which extends across to outer lip. Coloration fawnish with a whitish peripheral band, and sometimes a paler base, some shells unicolor fawn. Apical whorl smooth, adult whorls three and one half, dull, with faint growth striae but no spiral striation. The umbilical pad is

roughened, the columella short, straight, the operculum thick, horny. The specimens before me from Baudin Island, presented by the collector J. J. Walker, are apparently slightly smaller than the type measured by Smith, who gives "Diam. maj. 5, alt. 3.5 mm.": these are about 4 mm. in breadth by 3 mm. in height.

FAMILY CYCLOPHORIDAE.

This family does *not* occur in Western Australia, though two species were described by Benson as having been collected at the Swan River by Dr. Bacon. As this collector also worked in India it is apparent that the localities became confused, and the Cyclophorids described originated in India. The names were *Cyclostoma liricinctum* and *C. orbiculatum* Benson, Ann. Mag. Nat. Hist., Ser. II. , Vol. XI., p. 106, February, and they were figured by Reeve, Conch. Icon. Vol. XIII., *Cyclophorus,* Vol. XX., sp. 100 and 101, Aug. 1861. They can now be completely dismissed from this fauna.

Subclass PULMONATA.

This subclass includes all the land snails save those with an operculum, and as only one of the latter comes into our review, the remaining members of our fauna here follow. Numerous smaller divisions are utilised in classifying this large number.

Order STYLOMMATOPHORA.

The subclass is separated into two Orders, but only one is represented in this fauna, but this has been subdivided into many large groups, but as they seem somewhat artificial, only the families are here mentioned.

FAMILY VERTIGINIDAE.

This family name was previously used for all Australian pupoid shells, but as now restricted, no representative is yet known from Western Australia, but as the species are very small and difficult to find and so little searching has yet been done in this land it cannot be definitely stated that the family is absolutely absent from the State.

FAMILY GASTROCOPTIDAE.

The minute Pupoid shells of Australia were placed in one family in the Basic List, following Pilsbry's Monograph, but upon reconsidering the species in connection with the South Australian forms I regretted that action. I merely noted my objection in my account, but here allocate the Western Australian shells in a more scientific manner. It became quite obvious that we were dealing with diverse stocks, and then it was seen that Pilsbry himself had been dubious of his own action. Steenberg, a European authority, has given an excellent account of the anatomy of these difficult minutiae, and separated the Palaearctic forms into many families. Following this worker, the Australian species would be arranged in four families, and this is much nearer the truth. The few Western Australian species then fall into three families:

Shell very small, pupoid, with small mouth with complex armature; species dextral or sinistral.

Gastrocoptidae.

Shell small, but larger than preceding, with no armature in mouth save a tubercle or base of shell adjacent to outer lip.

Pupoididae.

Shell very small, stouter than first named, mouth armature not so complex and folds differently placed.

Pupillidae.

Genus **AUSTRALBINULA** Pilsbry 1916.

1916—*Australbinula* Pilsbry, Man. Conch. (Tryon), 2nd Ser., Vol. XXIV. (pt. 93), p. II., Dec. '18: id. (pt. 94) pp. 155/166, July 18, 1917. Orthotype *Gastrocopta hedleyi* Pilsbry.

Small Pupoid shells, dextral, rarely sinistral, faintly striate, with the small mouth almost closed by teeth blocking the aperture: a large columellar tooth; on the base of the shell one to three, called the parietal teeth, one of which is generally larger than the others; and on the inside of the outer lip three or four, called palatal, teeth. All the shells are small, up to 3 mm. in length, and must be examined microscopically for differentiation.

Australbinula wallabyensis Smith 1894.

1894—*Pupa wallabyensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 97, June. East Wallaby Island, Houtman's Abrolhos (Walker).

1916—*Bifidaria wallabyensis* Hedley, Journ. Roy. Soc. West. Aust., Vol. I., p. 217 (68 in sep.).

1917—*Gastrocopta wallabyensis* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XXIV., pt. 94, p. 171, July 18.

Unfortunately this species has not yet been figured, and no specimens from the Abrolhos are available. Smith described it in great detail as follows: "Shell dextral, cylindrical, pellucid, white, narrowly rimate; whorls five, very convex, sutures profoundly impressed, very obliquely striate, the last whorl ascending at the aperture; spire cylindrical, obtuse to the apex; aperture very small, ringent, one fourth the total length of the shell, furnished with seven unequal teeth (three very small parietals, the middle one largest, one large columellar lamelliform tooth, three large lamelliform palatals); peristome lightly expanded, margins approaching, joined by a thin callus. Length 2.5, diameter 1 mm. *Hab.*, East Wallaby Island, Houtman's Abrolhos (Walker). The teeth of this species are very characteristic, and block up the aperture to a considerable extent. The three parietal are much smaller than the rest, and situated close together, the central one being the largest. That on the columella is large, lamelliform, and prominent. The central palatal tooth is narrow, long, and extends inwards; those on each side of it are shorter, but a trifle more prominent perhaps. *P. Macdonnelli*, Brazier, from Fitzroy Island, N.E. Australia, is a little shorter than this species and has more feeble armature in the aperture." Pilsbry added: "Mr. B. B. Woodward, who has kindly examined the type specimen for me, states that the columellar lamella ascends within. The species is therefore related to the polymorphic *G. larapinta*. It differs by the unusually small aperture (only one-fourth the total length, while in *larapinta* it is at least one-third), and the narrower contour of the shell."

Australbinula complexa sp. nov.

Plate 1. Fig. 7.

Pilsbry (Man. Conch. (Tryon), Ser. II., Vol. XXIV. (pt. 94), p. 170, July 18, 1917) proposed *Gastrocopta larapinta deserti* for a form of pupoid shell, picked out of series sent from Central Australia by Professor Tate as

"mooreana." Various Centralian localities were confused, and Pilsbry added Forrest River, North-Western Australia, an indiscreet addition. However he figured the specimens so that separation is easy. His first measurement of his *"deserti"* is length 2.25, diameter above aperture 1.15 mm., and that agrees with his figure 3 on plate 2, which is here selected as type. His figure 1 shows a more slender shell also without locality.

Mr. E. Sedgwick has sent from Nangeenan via Merredin shells recalling this figure 1 in form, but with the whorls even less rounded and the tip more obtuse. The angular lamella is more pronounced and there is a notable basal fold present. The type measures 3 mm. in length by 1.25 mm. in breadth.

Australbinula helmsiana sp. nov.

Plate 1. Fig. 2.

1917 *Gastrocopta larapinta deserti* Pilsbry, Man. Conch., (Tryon), Ser. II., Vol. XXIV., p. 171, pl. 30, fig. 1, July 18. Specimens only from Forrest River, North-Western Australia (R. Helms).

At the place quoted Pilsbry recorded that these specimens, one of which he figured was "a little larger, 2.5 to 2.55 mm., long, diameter 1.1 mm., or 2.4. 1.2 mm. There is no brownish tint except what may be caused by the dried animal. There is a small infraparietal nodule in some examples, wanting in others. The columellar lamella has a rounded outline and ascends obliquely inward. Lower parietal plica is strong, the upper smaller and far shorter. There is no basal fold. The lip expands broadly." Shell minute, cylindrical, dextral, whorls round, sutures deep, spire obtuse, sculpture delicate oblique striae, mouth with outer lip expanded, aperture with intrusive teeth as noted above.

Australbinula mooreana Smith 1894.

Plate 1. Fig. 4.

1894—*Pupa mooreana* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 97, pl. VII., fig. 25, June. Roebuck Bay, North-West Australia.

1916—*Bifidaria mooreana* Hedley, Journ. Roy. Soc. West Austr., Vol. I, p. 217, (p. 68 in separate).

1917—*Gastrocopta mooreana* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XXIV. (pt. 94), p. 160, pl. 30, fig. 4 (copied from Smith): Vol. XXVI. (pt. 104), p. 230, pl. 24, fig. 6, 7, Nov. 1921: paratypical specimens figured.

"Easily distinguished by the sculpture."

Striae irregular, interrupted by malleation or shallow uneven pitting the parietal lamella is not connected with the angular lamella which is straight, the parietal not very long and only slightly curved. There are only two palatal folds, the lower being larger and almost taking the place of the basal which is missing. The columellar lamella is deeply set and straight. Perhaps nearer *ficulnea* than *Gastrocopta* the angular laminae being present but not connected: this feature may be of value in either connection, hence to indicate this abnormality the new subgeneric name **Westralcopta** is here introduced. Pilsbry's account of paratypes is here added for reference: "The shell resembles *G. larapinta* in contour, but has a special character in the sculpture as seen under the microscope, the striae being made irregular, and in places interrupted by *malleation* or shallow, uneven pitting, producing sometimes a sort of reticulation, not unlike that of some Nesopupae (*Indopupa*). The

straight angular lamella joins the lip weakly or scarcely. It *does not connect* with the parietal lamella, which is high but not very long. The columellar lamella is high on the columella, and ascends very slightly inward, being nearly horizontal. There are two short palatal folds, the lower being larger and somewhat more immersed. No basal fold. Peristome reflected and thickened moderately within. Length 2.2, diam. to edge of lip 1.2 mm.; 5½ whorls."

FAMILY PUPOIDIDAE.

The small pupoids assigned to this family are generally larger than the remaining Australian pupoid shells, and are either sinistral or dextral, rather stoutly built, not conspicuously sculptured, and with the mouth rather square the outer lip expanded, and a parietal lamina, which lies adjacent to the junction of the outer lip.

Genus **THEMAPUPA** Iredale 1930.

1930—*Themapupa* Iredale, Vict. Naturalist, Vol. 47, p. 120, November. Haplotype *Pupa beltiana* Tate.

The definition above given applies to the Australian members of the family.

Themapupa contraria Smith 1894.

1894—*Pupa contraria* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 96, June. East Wallaby Island, Houtman's Abrolhos (Walker).

1916—*Pupoides contrarius* Hedley, Journ. Roy. Soc. West Austr. Vol. I., p. 217 (68 in sep.).

1921—*Pupoides contrarius* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XXVI. (pt. 103), p. 144 (not. pl. 15, figs. 9, 10 *eremicola*), August 4.

As this shell has not yet been figured, and we have no Abrolhos material, Smith's description is reproduced: "Shell sinistral, rimate, fuscous horny, obliquely very finely striate; whorls 5½, convex, separated by a deep suture, the last whorl scarcely broader than the one preceding, ascending at the aperture; spire elongate, convex, pyramidal, subglobose at the apex; aperture one-third the total length; peristome white, expanded, margins joined by a thin callus, a tubercle near the insertion of the lip. Length 4.5, breadth 2 mm. Aperture 1.5 mm. long. This species may possibly prove to be the sinistral form of *P. adelaidae* Ad. and Angas, which is only known to me by the description."

P. adelaidae is obviously a larger shell, as is *eremicola* with which the present species was later associated.

Themapupa sinistralis Pilsbry 1921.

1894—*Pupa pacifica* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 96, June. Cassini I., N.W. Australia (J. J. Walker).

1921—*Pupoides pacificus* form *sinistralis* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XXVI. (pt. 103), p. 144, Aug. 4.

When Smith recorded the East Coast *pacifica* from North-West Australia he noted: "All the specimens from Cassini Island are sinistral; otherwise they resemble the normal form."

Pilsbry, in accepting this determination, observed that numerous specimens from all the other localities admitted furnished dextral specimens alone and recorded the Cassini Island shells as a form *sinistralis*, and this name may be used specifically to keep this shell under review.

Themapupa lepidula A. Adams and Angas 1864.

Plate I., figs. 5 and 5a.

1864—*Buliminus (Chondrula) lepidula* A. Adams and Angas, Proc. Zool. Soc. (Lond.), 1864, p. 38, June 24. Shark Bay, W.A. Fig'd. Cox, Mon. Austr. Land Shells, p. 69, pl. XIX., f. 14, May, 1868, from a painting of the type by Angas.

1894—*Pupa lepidula* Smith, Proc. Malac. Soc. (Lond.), 1894, p. 96, June, cites "Cox, op. cit., p. 69 (unfigured)."

1916—*Pupoides lepidulus* Hedley, Journ. Roy. Soc. West. Austr., Vol. I., p. 217.

1921—*Pupoides pacificus* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XXVI. (pt. 103), p. 141, August 4 (part).

This is a very distinct species judging from Cox's figure of the type which is here reproduced. Pilsbry rather carelessly included it in the synonymy of *P. pacificus,* observing, "It came from well within the known range'' of that species, whereas it was well outside. Then he figured a specimen from Forrest River, near Wyndham, which was not much like Cox's figure, and noting that the lip was narrower concludes, "If this proves constant they might be separated as a race *lepidula.*"

The original description is here added as no one has collected land-shells at Shark Bay in recent years: "Shell turrited, pupiform, umbilicate, thin, glossy, semipellucid, corneous; whorls 5 strongly convex, longitudinally striate. Aperture rotund-ovate; peristome interrupted, white, broadly reflected; outer lip provided above with a small, white, tuberculiform callus. Length 2, width 1 line. This little species differs from *C. adelaidae* in being semipellucid, shining and of a horn colour. The whorls, moreover, are much more strongly convex."

In view of the fact that species have been confused under the name *pacificus*, it is somewhat amusing to record a recent conclusion. Rensch (Zool. Jahrbuch. (Syst.), Jena Bd. 63, heft I., pp. 1-130, Apl. 12, 1932), led astray by a desire to recognise affinities without regard to local conditions, has proposed to admit one species *Pupoides coenopictus* Hutton, with an old-world range as follows:—

P.c. coenopictus Hutton. India, Ceylon, Afghanistan.

P.c. senegalensis Morelet. West Africa.

P.c. connectens nov. Sumba.

P.c. pacificus Pfeiffer. Australia, Islands of Torres Straits.

The idea of introducing a new subspecies, in an amalgam of such a composition, does not seem in accordance with his own theory of widespread "races." These "races" appear to be superspecies of other malacologists.

Themapupa anapacifica sp. nov.

Plate I., fig. 9.

1874—*Bulimus pacificus* Smith, Zool. Erebus & Terror, Moll., p. 3, pl. IV., f. 6. Pigeon I. N.W. Australia (Richardson). Not *B. pacificus* Pfeiffer, Proc. Zool. Soc. (Lond.), 1846, p. 31.

1894—*Pupa pacifica* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 96, June. Pigeon I., near Wallaby I., Houtman's Abrolhos, West Australia; Roebuck Bay and Baudin I., N.W. Australia (J. J. Walker).

1921—*Pupoides pacificus* Pilsbry, Man. Conch., Ser. 2, Vol. XXVI. (pt. 103), p. 141, pl. 15, fig. 14 only, Aug. 4. Forrest River, East Kimberley District (Richard Helms).

The Western shell has been associated with *pacificus* by Smith, and Pilsbry, although the latter noted the discontinuous distribution, and figured as representative of a North Queensland island shell, specimens from Narrabri, inland New South Wales, Forrest River, West Australia, and apparently only one from Facing Island, almost in the south of Queensland. The last named, as would naturally be concluded, appears to be the nearest to the true *pacifica*. The Forrest River shell is here named. Shell small, pupoid, dextral, whorls convex, sutures deeply impressed, umbilicate, apex obtuse, coloration pale brown, outer lip white. The apical whorls are smooth, the adult whorls obliquely finely striated with threads, in some cases well marked, the mouth rather small. Length 4.25 mm.: breadth 2 mm.

Themapupa dirupta sp. nov.

Plate I., fig. 8.

Mr. W. W. Froggatt collected a few specimens of a pupoid shell in the Barrier-Napier Range, and these break up the "*pacifica*" phantasy.

They are definitely of that association, but also perfectly distinct, being smaller than any of the so-called forms, measuring 3.5 mm. length by 1.5 mm. in breadth. The whorls are flatter than in the previous species though the sutures are deep, the shell darker coloured, the sculpture weaker, the mouth comparatively larger, the shell having a more squat appearance.

This is apparently the first inland representative in Australia of the "*pacifica*" series.

Themapupa beltiana Tate 1894.

Plate I., figs. 3 and 6.

1894—*Pupa beltiana* Tate, Trans. Roy. Soc. South Austr., Vol. XVIII., p. 191, November. Central Australia.

Fig'd Rep. Horn Sci. Exped. Centr. Austr. (pt. II.), Zool., p. 204, p. XVIII., fig. 15, Feb. 1896 (as dextral form of *P. contraria* Smith).

1921—*Pupoides contrarius beltianus* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XXVI. (pt. 103), p. 145, pl. 15, figs. 5, 7, 8, August 4.

Apparently there is definite local variation in this species as well as individual variation, and a good series from Cardanumbi shows all the specimens to be broader than cotypes of *beltiana*. These may be regarded as a subspecies **T. b. contexta** nov. The type measuring 6 mm. in length by 2.75 mm. in breadth, some even being broader, whereas the type of *beltiana* was only 4.5 mm. in length by scarcely 2 mm. in breadth, paratypes being more slender still. A series from Nangeenan via Merredin collected by Mr. E. Sedgwick, shows a more conical form than any of Pilsbry's excellent figures, recalling a dextral fig. 9 (*contraria*). The shells are variable in size but all show the same shape, the whorls flatly rounded, the sutures deep, the angular nodule rather small, and may be called **T. b. asserta**, subsp. nov., the type measuring 5.5 mm. in length and 2.5 mm. in breadth.

FAMILY **PUPILLIDAE.**

The usage of northern families for southern shells will probably later be as amusing to our successors as some of our predecessors' work is to ourselves. Nevertheless it is necessary to have some refuge for these waifs, and therefore the above is here used with reservation.

Genus **OMEGAPILLA** Iredale 1937.

1937—*Omegapilla* Iredale, Austr. Zool., Vol. VIII., p. 304, March 12. Orthotype *Pupa nelsoni* Cox.

Small pupoid shells, dextral or sinistral, mouth small, teeth three or four, differently arranged from those of other Pupoids, though obviously correlative.

Hedley placed this in the European genus, *Vertigo,* while Pilsbry includes it in the Palaearctic genus, *Pupilla,* under a section, *Primipupilla,* based on a Caucasian shell, but later discarded this in favour of *Gibbulinopsis* Germain, proposed for an "Enneid" shell from the Island of Reunion.

I reiterate my conclusion that the association of southern Australian Pupoids with those from Europe and South Africa is basically unsound, and should not be recognised by Australian conchologists.

Omegapilla occidentalis sp. nov.

Plate I., fig. 10.

1894—*Pupa lincolnensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 961, June. Pigeon Island, near Wallaby Island (Dr. Richardson, in British Museum), and East Wallaby Island, Houtman's Abrolhos (Walker).

1916—*Vertigo lincolnensis* Hedley, Journ. Roy. Soc. West Austr., Vol. I., p. 217 (p. 68 in separate).

1921—*Pupilla australis* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XXVI. (pt. 104), p. 218.

Smith remarked "This species is described [by Cox (Mon. Austr. Land Shells, p. 80, pl. XV, fig. 16, May, 1868; Port Lincoln, South Australia)], as having only a single tooth or tubercle in the aperture. The specimens collected by Dr. Richardson and Mr. Walker have a second basal tubercle as indicated in Cox's figure, and a third far within upon the columella. It is possible that in the examples examined by Dr. Cox the denticles were only feebly developed, or they may even have been overlooked, being rather indistinct."

Many specimens from Rottnest I. are much smaller than South Australian *lincolnensis* or *australis,* and have the teeth placed much further back and less noticeable, the parietal tooth most pronounced, the columellar one smaller and more hidden, the basal one well inside.

FAMILY **SUCCINEIDAE.**

This family is at present allowed a world-wide range, but this is questionable, and recent researches into British forms show distinct groups definable in that small compact area. I have therefore introduced the generic name *Austrosuccinea* for the common southern Australian type as the animal has been shown to differ from that of the northern group whose shell is most like. For a second peculiar Australian group I have proposed *Arborcinea*: both these occur in Western Australia but there may be a third later separated.

Genus **AUSTROSUCCINEA** Iredale 1937.

1937—*Austrosuccinea* Iredale, Austr. Zool., Vol. VIII., p. 307, Mch. 12, Orthotype *Succinea australis* Ferussac.

The waxy appearance and peculiar form make these molluscs recognisable at sight. Subbulimoid in form with a very short spire and open oval

mouth, imperforate, texture very thin, the outer lip fragile, sculpture of rude growth radials, sometimes with fine subordinate lining.

Austrosuccinea scalarina Pfeiffer 1861.

Plate I., fig. 11.

1861—*Succinea scalarina* Pfeiffer, Proc. Zool. Soc. (Lond.), 1861, p. 28, May 1. King George's Sound, South-West Australia. Fig'd. Cox, Mon. Austr. Land Shells, p. 89, pl. XX, fig. 19, May, 1868, from a painting of the type by Angas.

"Shell ovately conical, scalarine, rather solid, irregularly rugosely plicated, slightly shining, reddish; spire elongated, rather acute; whorls $3\frac{1}{2}$, convex, last slightly exceeding the spire, somewhat attenuated at the base; columella receding, nearly straight, forming with the peristome an indistinct angle; aperture oblique, oval, scarcely angular above, peristome simple, columellar margin slightly reflected above."

Such is the description of a *Succinea*, and is here reproduced as a standard. The shell is reddish when alive but commonly fades to horny, the solidity is usually missing, thin and fragile better describing the species; length 15 mm.; breadth 7.5 mm.; length of aperture 9 mm.

Austrosuccinea contenta sp. nov.

Plate I., figs. 12 and 13.

1843 *Succinea oblonga* "Dr." Menke, Moll. Nov. Holl. Spec., p. 6 (Apl. 11), *nom. nud.*, in cracks of limestone rocks not far from the sea near Perth.

1844—*Succinea oblonga* Menke, Zeitschr. für. Malak. (Menke), 1884, p. 56, Apl. 10. New Holland specimens described.

Not *Succinea oblonga* Draparnaud, Tab. Moll. France, p. 56, 1801.

Probably there are many species in the Perth district, but obviously Menke's name was used for the common one.

This has a short spire with a rather swollen body whorl, the spire shorter than that of *scalarina* and the body whorl a little broader; the shell is not so rugose, the early whorls being much smoother, the inner lip is a little thickened and a slight body glaze connects with the outer lip. The length of the type is 11 mm., the breadth 7 mm., the length of the aperture 8 mm.

Specimens from Rottnest Island appear to differ in their narrower form, less swollen body whorl, longer spire and may represent a distinct subspecies, **A. contenta isolata** subsp. nov., but this will be more fully discussed later. The type measures 11 mm. in length, 6 mm. in breadth and the aperture 6.5 mm. in length.

Austrosuccinea caurina sp. nov.

Plate I., fig. 16.

1895—*Succinea scalarina* Hedley, Proc. Malac. Soc. (Lond.), Vol. I., p. 260, July. Fitzroy River, North-West Australia.

1898—*Succinea scalarina* Ancey, Proc. Linn. Soc. N.S.W., Vol. XXII., (1897), p. 777, June 4. Lennard River, 100 miles inland from Derby, North-West Australia (W. W. Froggatt).

This north-western species which has been confused with the south-western one has a general superficial resemblance to that, but is smaller, nar-

rower and lacks the rugose plications. This reads very similarly to the description of *strigillata* but the shape is different.

Shell elongate, rather narrow, spire moderate, attenuate, mouth oval not much expanded, sculpture weak, early whorls almost smooth. The whorls are rounded, but not strongly convex, the sutures fairly deep. There is very little body glaze connecting the inner and outer lips. Length of type 12 mm., breadth 6.25 mm., length of aperture 7 mm.

Austrosuccinea strigillata A. Adams and Angas 1864.

1864—*Succinea strigillata* A. Adams and Angas, Proc. Zool. Soc. (Lond.), 1864, p. 38, June 24. Shark Bay, West Australia.

Fig'd. Cox, Mon. Austr. Land Shells, p. 89, pl. XV., fig. 5, May, 1868.

No specimens are available from Shark Bay so the original description is here given: "Shell ovately conical, thin, semi pellucid, pale horny yellow; spire scarcely equalling the aperture; apex papillary; whorls 3½, strongly convex, longitudinally finely and minutely striated; aperture oblong ovate; left margin with a long thin callus deposit, right simple. Length 5 lines, breadth 2½ lines. A species somewhat allied to *Succinea strigata* Pfr., from South Australia, having the same papillary apex; but differing in being smaller, thinner, of a lighter colour, and in the whorls being less strongly rugose."

Smith (Proc. Malac. Soc. (Lond.), Vol. I., p. 97, June, 1894) has recorded *Succinea scalarina* from E. Wallaby I., Houtman's Abrolhos, W.A., and given a figure but whether this be from the type of *scalarina* or from an Abrolhos shell is not stated. At present as no specimens are available the identity of the island form cannot be ascertained.

Austrosuccinea aridicola sp. nov.

Plate I., fig. 15.

Shells collected at Boulder by W. D. Campbell are unlike any of the coastal forms, but still more unlike the Centralian *interioris*. Shell small, elongate, spire long, mouth short of moderate expansion, whorls very rounded, sutures very deep. The shells are dead, the periostracum missing, the sculpture weakly strigose, the strigations still notable on the early whorl. The spire is almost as long as the aperture, the latter being rather a regular oval, the inner lip connecting with a body glaze to the outer lip, which is thin as usual. Length 10.5 mm., breadth 6 mm., length of aperture 5.5 mm.

Austrosuccinea coxi Finlay 1927.

Plate I., fig. 17.

1927—*Succinea coxi* Finlay, Trans. New Zeal. Inst., Vol. 57, p. 521, Jan. 19, new name for

1868 *Succinea aperta* Cox, Mon. Austr. Land Shells, p. 90, pl. XVII., fig. 6, May. King George's Sound, West Australia (Masters).

Not *Succinea aperta* Lea, Trns. Amer. Phil. Soc., Vol. VI., p. 101, 1838.

This species is recognisable at sight by the large mouth which is the bulk of the shell, the spire being only one-third the length of the aperture. From conchological features alone it deserves separation subgenerically as **Cerinasota** nov., and it is fairly certain that the anatomy will necessitate a higher value.

Genus **ARBORCINEA** Iredale 1937.

1937—*Arborcinea* Iredale, Austr. Zool., Vol. VIII., p. 308, Mch. 12. Orthotype *Succinea eucalypti* Cox.

The tree living Succineids have very different habits from those on the ground which frequent damp places, and it has been recently argued that field observations must be taken into account in the taxonomic disposition of our molluscs. I recorded many years ago that on Sunday Island, Kermadec Group, the tree living snails were altogether unrelated to those living on the ground adjacent. In the present series the tree living Succineids live under the bark of the trees and seal themselves to the wood, carrying a thick epiphragm. Normal Succineids with a large animal live in moist places, and many kinds have been separated among those alone. The shell features of *Arborcinea* include a short spire, swollen body whorl and a rather bold sculpture with a truncated thickened columella.

Arborcinea menkeana Pfeiffer 1850.

Plate I., fig. 14.

1843—*Succinea amphibia* "Dr." Menke, Moll. Nov. Holl. Spec., p. 6, Apl. nom. nud. "Under the Bark of Eucalypts." District Hay, West Australia.

1844—*Succinea amphibia* Menke, Zeitschr. für Malak (Menke), 1844, p. 55, Apl. 10. Specimens described.

Not *S. amphibia* Draparnaud, Tab. Moll. France, p. 55, 1801.

1850—*Succinea menkeana* Pfeiffer, Zeitschr. fur Malak (Menke), 1849, p. 110, Jan. 1850, fide C.D.S. New Holland (L. Preiss) = *amphibia* Menke, i.e., from Hay as above.

Fig'd. Pfeiffer, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth XI., p. 45, pl. 4, figs. 36, 37, 38. 1855.

1930—*Succinea brevissima* Thiele, Die Fauna Sudwest Australiens, Bd. V., lief 8, p. 587, pl. IV., f. 66. Collie, South-West Australia.

The description indicates the genus thus "Shell ovately-elliptical, thin, distinctly striated, pellucid, shining, horny; spire short, papilliform, suture deep; whorls 2½, the last but one very convex, the last attenuated at the base; columella somewhat callous, regularly curved; aperture slightly oblique, regularly oval; peristome simple, thin, margins approaching. Length 3½ lines; breadth 1⅚ lines."

FAMILY **BOTHRIEMBRYONTIDAE.**

Probably the most intriguing land shells in Australia are the bulimoid forms inhabiting the South-West corner. A large number of species and races has developed, and probably only a tithe has been described. It is unfortunate these have not yet been studied by anyone conversant with local conditions, and it is certain that they will provide future students with much research. No more exciting subject could be chosen by the student, but the unravelling of the many problems will necessitate much investigation. The present essay, also by an outsider, is the result of over a dozen years of consideration, the specimens having been handled from every viewpoint, geological data, botanical data, meteorological data and even soil conditions have been brought under review. The first species were described from the collections of the French naturalists; a little later similar shells taken by British

ing to the coast from there to Cape Leeuwin and thence still coastwise to 70 miles east of Israelite Bay. Though apparently a coastal group, it has not been collected yet on the islands of the Recherche Group, although one species comes from Doubtful Island, a coastal islet. On the other hand, the true *Bothriembryon* is abundant on the islands of the Recherche Group and the mainland adjacent, and then from King George's Sound seems to make an inland march across to Perth. It has not yet been recorded from the Stirling Ranges where a peculiar *Telembryon* lives alongside *Dialembryon.* The range of this last-named group is peculiar, species being known from the Darling Ranges inland from Perth, the Stirling Ranges and the hazel scrubs a little west of King George's Sound. Still more curious is the distribution of the giant *Ponembryon,* which appears somewhere about King George's Sound and occurs eastward to the Fraser Range. This leaves *Hartogembryon* and *Satagembryon,* which are localised, and as above noted these may be only specialised offshoots from *Bothriembryon* and *Telembryon* respectively. A glance at a rainfall chart will show that these larger groups are *not* governed by present-day rainfall, though investigation suggests that species vary in accordance with the annual rainfall. Furthermore, it seems that certain trees live under certain geological conditions, and that some of these snails are associated with definite botanical formations. This cannot be definitely asserted as there are too little data, but it would be a good line to follow.

The species are easily distinguishable, but there is a lot of individual variation. No mechanical method of diagnosis can be used, though examination of series enables differentiation with ease. Consequently the norm of the series is here described and the connectant variation recorded, but specimens must be available for comparison and recognition. Figures without confirmative shells can prove very misleading, whereas topotypes are of very definite value and few mistakes will be made in their use.

Genus **BOTHRIEMBRYON** Pilsbry 1894.

1894—*Bothriembryon* Pilsbry, Nautilus, Vol. VIII., p. 36, July. Orthotype *Bulimus melo* Quoy and Gaimard.

1861—*Liparus* Martens, Die Heliceen (Albers), 2nd ed., p. 229. Orthotype *Bulimus inflatus* Lamarck.
Not *Liparus* Albers, Die Heliceen, 1st ed., p. 172, 1850.

1933—*Hartogembryon* Iredale, Rec. Austr. Mus., Vol. XIX, p. 41, Aug. 2. Orthotype *Bulimus onslowi* Cox.

1933—*Larapintembryon* Iredale, Rec. Austr. Mus., Vol. XIX, p. 41, Aug. 2. Orthotype *Liparus spenceri* Tate.

1933—*Satagembryon* Iredale, Rec. Austr. Mus., Vol. XIX., p. 41, Aug. 2. Orthotype *Buliminus gratwicki* Cox.

The characters of the genus, as here used, are those already fully detailed in connection with the family just preceding.

Bothriembryon melo Quoy and Gaimard 1832.

Plate II., fig. 1.

1832—*Helix melo* Quoy and Gaimard, Voy Astrol. Zool., Vol. II., p. 109, pl. 9, figs. 4-7. Summit of Bald Head, King George's Sound, South-West Australia.

explorers being made known. A German naturalist then collected some specimens, and these, of course, were dealt with by German conchologists. Some time later Cox, the Sydney conchologist, listed the species in his Monograph, but was content to indicate the various varieties only. Hedley attempted to arrange the forms but did not publish his conclusions.

A real attempt to systematise them was made by the inimitable American malacologist, Pilsbry, in the "Manual of Conchology." To assist him, Cox sent him a large collection but unfortunately the bulk of that collection was labelled "King George's Sound," the name covering all the adjacent locality within a radius of a hundred miles or so. Thus Pilsbry was baffled with the great variation in the shells from this locality. It is indeed fortunate that the Cox collection, including the specimens handled by Pilsbry, is now in the care of the Australian Museum, and has been utilised in this study. A year or so later the German monographer, Kobelt, dealt with this group, and in the main followed Pilsbry, but did not realise the value of exact localities. In the future the science of geozoology will probably play a great part in the elucidation of this group, as the species and even higher groupings appear to be living in government by their geological and botanical environment, with, of course, the rainfall being a matter of importance.

The Bothriembryontids vary in size from about 25 mm. to 50 mm. in length, from very narrow to plump in form, and from almost smooth to heavily granose sculpture. It is probable that future investigators will discover anatomical features in the animal to assist them, but at present only the shells are available for examination.

The notable variations are easily seen, as *dux, indutus, melo, onslowi, kingii* and *gratwickii.* According to Pilsbry's researches these appeared to show different apical features so that as a guide for future investigators I introduced subgeneric names, *Hartogembryon* for *onslowi,* and *Satagembryon* for *gratwicki.* The type of *Bothriembryon* is *melo,* and *Hartogembryon* seems to be an offshoot from this source, while *Satagembryon* may be a specialised product of the *kingii* root. However, *dux* and *indutus,* the two largest forms, are thus left nameless, and while the latter may be related to the *melo* branch, it is now differentiated clearly, and is here subgenerically named **Dialembryon.** The source of *dux* is at present indeterminable, and a subgenus **Ponembryon** is here proposed to distinguish it. As *Satagembryon* is so abnormal, a subgenus **Telembryon,** is introduced for the normal *kingii* series. By the usage of these subgeneric names, and the allotment of the named species will secure greater accuracy and lead to a better knowledge of this interesting series of land-shells. It must be pointed out, however, that though *dux* and *indutus* are in no danger of confusion, there are some shells that appear to link together *kingii* and *melo,* but better material and more local knowledge might easily dissipate the clouded outlook of the extra limital struggle for light in this delightful molluscan group.

The Bothriembryontids are practically confined to the south-west corner of Western Australia, which I have called the Leeuwinian Area, and constitute a remarkable element of the Autochthonian Faunula. Northwards the group reaches Shark Bay, there mingling with the outliers of the Caurine Faunula of the Dampierian Sub-Area. Eastwards a few members range along the southern sea coast of the Centralian or Larapintine Area, while one form is found in the middle of this Area, among the true representatives of the Eremian or Eyrean Faunula. Now, in this Leeuwinian Area the groups abovenamed already seem to be limited in their distribution. Thus we have *Telembryon* from Vasse just north of Cape Naturaliste, then cling-

1832—*Helix melones* id. ib., in synonymy, ex Ferussac, Tabl. Syst. Limaçons, Prodr., p. 58, Jan.: p. 54, June, 1821 (*Helix*) (*Cochlogena*) *melones* nom. nud. cf. Potiez & Michaud, Gal. Molus. Mus. Douai, Vol. I., p. 147, pl. XIII., fig. 15-16, 1838.

1838—*Bulimus ovum* Deshayes, Règne Animal (Cuvier) Disciples ed., pl. 23, fig. 1, Quoy MS. ? error only for *melo*.

1839—*Bulimus melo* Sowerby, Zool. Beechey's Voy., p. 145, pl. 38, fig. 16. "n.2 error."

1843—*Bulimus melo* Menke, Moll. Nov. Holl., Spec. p. 7, April "four varieties described. Among Melaleuca in Hay district.

1843 *Bulimus physodes* Menke, id., ib., as synonym of var. a. of the preceding.

1844—*Bulimus melo* Menke, Zeitschr. für Malak. (Menke), 1844, p. 56, April 10. The above varieties discussed, and var. a. recognised as typical *B. melo* Quoy & Gaimard.

1859—*Bulimus melo* Pfeiffer, Mon. Helic. viv., Vol. IV., p. 477, six varieties differentiated, but not named.

1868—*Bulimus melo* Cox, Mon. Austr. Land Shells, p. 74, pl. XIII., fig. 6, May.

1892—*Liparus inflatus*, with vars. *melo*, *physodes*, *castaneus*, *bulla* and *rhodostoma*, Hedley, Rec. Austr. Mus. Vol. II., p. 29, Aug.

1900—*Bothriembryon inflatus* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 3, pl. 1, figs. 1-5, apex, pl. 4, figs. 73, 74, April 23 and var. *melo*, p. 4, pl. 1, figs. 7-10, (other vars. not referable here).

1900—*Bothriembryon physoides* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XIII., p. 9, pl. 2, figs. 35-36-37, Apl. 23.

1901—*Bothriembryon physalis* Kobelt, Syst. Conch. Cab. (Mart & Chemn.), ed. Kuster, Bd. I., Abth. XIII (2), p. 778 (28: vii: 1907) error only.

Shell elongately conical, rather plump, spire conical not quite as long as aperture, whorls rather flattened, sutures lightly impressed, last whorl two-thirds the length of the shell, mouth oval, elongate, lip thin, columella straight, reflected, hiding, but not closing, a deep narrow umbilicus.

The coloration is commonly unicolor, pale fawn, sometimes with a sub-sutural reddish band and red longitudinal streaks but never with a red circumbilical patch. Dead shells are white as the coloration lies in a very fine periostraeum.

The apex is rather flattened, of two whorls, the sculpture of fine punctuation or thimbling as it is sometimes termed, this being coarser than that of the Swan River *bulla;* the adult sculpture consists of radial growth lines, irregular and wavy, becoming less marked on the last whorl. On the early whorls there is a faint concentric sculpture also seen but this is never notable and usually vanishes early. Length 26 mm., breadth 15.5 mm. This description is drawn up from specimens from the type locality, where a great deal of colour variation is not seen. As related below, many shells have been regarded as answering to the original nominations, but as now restricted the above applies exactly.

The confusion in connection with the common King George's Sound shell has lasted since its discovery. A similar shell was found in the Perth district, and another not a great deal unlike at Shark Bay. Apparently Férussac distinguished these, and Lamarck confused them, and then Quoy

and Gaimard re-recognised Férussac's form. Menke, however, could not understand them, and added some more species. Collections did not solve the problems, as the localities whence the shells came were not accurately distinguished. Hence we have the great authority on land-shells of eighty years ago, Pfeiffer (Mon. Helic. viv., Vol. IV., p. 477, 1859), allowing one species under the name *melo*, but arranging six varieties, which he did not systematically name, but used phrases only. The first words were afterwards recorded as varietal names, and these read *castaneus, luteus, major, albidus,* the fifth without a distinctive adjective to begin with, and the sixth, *tenius*, citing *physodes* Menke as equivalent. No localities were known for these different variations, and it is now impossible to determine these varieties. Cox mentioned Menke and Pfeiffer, and that he could add more varieties, but did not give any names. Hedley arranged the shells in the Australian Museum and gave names to two colour varieties as was the custom then, but did not publish these when he listed the species under the name *Liparus inflatus* Lamarck, with varieties, *melo* Q. & G., *physodes* Menke, *castaneus* Pfeiffer, *bulla* Menke and *rhodostoma* Gray. Pilsbry introduced the new generic name *Bothriembryon,* and using *inflatus* as the specific name, admitted as varieties *melo* Q. & G., *castaneus* Deshayes, and added var. *maculiferus* and var. *conispira,* allowing *physodes, bulla* and *rhodostoma* as different although he could not recognise the two last-mentioned. Kobelt did not know what to do, so recorded most of these following Pilsbry's descriptions, but not admitting his valuation. His account is too confused to need much discussion, his descriptions and figures being hereafter allotted as far as possible.

Bothriembryon castaneus Pilsbry 1900.

Plate II., fig. 2.

1900—*Bothriembryon inflatus* var. *castaneus* Pilsbry, Man. Conch. (Tryon), Ser. 2., Vol XIII., p. 5, pl. I., figs. 11, 18, April 23, ex Deshayes MS. (citing Vol. VIII., p. 245, Lamarck, Hist. 2nd ed., where it does not occur). King George Sound, West Australia—Doubtful Island, South-West Australia.

Quoy and Gaimard figured as a variation of their *Helix melo,* a narrower brown shell with a broad white peripheral band. This variation was included by Deshayes, but he did not assign it any name, writing, "var. (ietas) castanea: vitta cincta alba." Pilsbry used the name *castaneus* as a varietal one, copying Quoy and Gaimard's figure, but describing a specimen sent by Dr. Cox, which he also figured. I am selecting the latter as the type of Pilsbry's *castaneus,* as it was one of a series from Doubtful Island, and his specimen is here refigured. The Doubtful Island shells are constant in coloration and size, the sculpture being a little stronger, and the size a little less. Length 23 mm., breadth 12.5 mm.

Bothriembryon rhodostomus Gray 1834.

Plate II., figs. 3-7.

1834—*Bulimus rhodostomus* Gray, Zool. Soc. (Lond.), 1834, p. 67, November 25. New Holland (probably collected by Robert Brown at Goose Island, Recherche Group, W.A.).

Not *Bulimus rhodostoma* Reeve, and later authors.

1900—*Bothriembryon inflatus* var. *maculiferus* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 5, pl. I., figs. 12-14, Apl. 23. "King George Sound, South-West Australia." = Recherche Group based on a shell collected by Rossiter.

1901—*Bothriembryon martensi* Kobelt, Syst. Conch. Cab., (Mart. & Chemn.) ed. Kuster, Bd. I., Abth. 13 (2), p. 764, pl. 112, figs. 3, 4, (sheet dated 21 VI. 1901). New Holland.

Through lack of specimens this species has been overlooked, a different species being figured by Reeve, but with doubt, yet he has been followed. If the description had been studied, the shell would have been recognised as it is really quite good: "Shell ovate, perforate, solid, striate, whitish marbled with rose, cuticle thin, olivaceous, suture delicately circulated; whorls with two obscure posterior bands; throat roseate; peristome a little thickened; axis anteriorly deep brown. Axis 1¼; diam. ¾ unc."

The size and proportions do not fit any other species than the following. When it is realised that Robert Brown was on Goose Island, one of the Recherche Group, where this kind of shell is common, its recognition is easy. Reeve figured a different shell under Gray's name, but he doubted the association, and he was right in that doubt, as his specimen almost certainly came from the Perth district. Rossiter also collected specimens in the Recherche Group, and one of these was named by Pilsbry as the Coxian locality "King George's Sound" misled him. The remainder of Rossiter's specimens in the Brazier collection are labelled "Recherche Group."

One of the most interesting revelations of Australian conchological science was made by Mr. A. F. Basset Hull, who visited the Recherche Group, with the assistance of Messrs. Henry Grant and J. H. Wright of the Australian Museum. Many specimens were collected on the mainland at Esperance, and on the eastern islets of the Archipelago. They found that each locality showed a definite variety, and these are illustrated and diagnosed here.

At first sight these recall the King George Sound *melo*, but are larger, and restricting *rhodostomus* to the western islands of the Recherche Archipelago, those from the eastern ones are here described.

The Gunton Island shells may be called **B. rhodostomus hullianus** subsp. nov. The ground colour is pale brownish cream, a reddish brown band below the suture followed by a pale band, and then another reddish brown band above the periphery with a similar red brown patch around the umbilicus. The aperture generally pale creamy white inside, sometimes purplish, the columbella pale or dark purplish brown, rarely white. A strong wrinkling below the suture gives the subsutural red band a streaked appearance. In form, they are roundly elongate, the spire being about equal in length to the aperture. Some thirty specimens are still available, of which two are unicolor, the others constant. The variation in measurements is: 35 mm. in length by 18 mm. in breadth (type), 34 by 20, 34 by 17 and 31 by 20 mm. One shell from Rob Island (Mondrain) is smaller with the ground colour pinkish white, heavily streaked with purplish brown, the aperture and columella purplish, and probably comes nearest true *rhodostomus.*

A longer series from Charley Island shows more variation, the darker shells being brownish cream, longitudinally heavily streaked with dark brown, some are less heavily marked, the streaking being fewer, and bands showing through so that one almost agrees with the Gunton Island shell, and some are even unicolor. In the other direction, the streaks tend to coalesce until the last whorl is practically uniform dark purplish brown. The aperture varies in coloration, according to the exterior, from white with a rose columella, and outer lip internally, through pale reddish to dark purple. In shape some are comparatively plump while others have the spire lengthened,

but in none is the spire shorter than the aperture. Measurements read length, 40 mm. by breadth, 20 mm. (type), 38 by 22, 38 by 20, 35 by 20 to 32 by 20. These may be called **B. r. grantianus** subsp. nov. Another fine series from Rabbit Island (not Rabbit Island in King George's Sound) are similar in size and form to the preceding, but are paler throughout, and are here named **B. r. wrightianus** subsp. nov. The markings are always paler, and pallid shells are more numerous, while these are generally smaller, all the largest ones being streaked. Only one approaches the normal Gunton Island form coloration, and the measurements of the streaked shells are length 36 mm. by breadth, 21.5 mm. (type), 36 by 20, and 35 by 21 mm., while the pale unicolor shells measure 34 by 21, 34 by 20 and 33 by 17 mm. The shells from Woody Isle are a little smaller, with a pale cream zone below suture, and a pale patch on base, the whorl being brown streaked with dark purplish brown, the streaks almost coalescing on the last whorl and forming a broad band. The measurements are, length, 31 mm. by 17 mm., and 30 mm. by 18 mm. This may be called **B. r. perspectus** subsp. nov., and this leads to the mainland Esperance form.

The mainland shells, collected commonly at Esperance, recall *melo,* but are generally larger and paler. Pilsbry has figured this as *maculiferus*, fig. 14, but as his figs. 12 and 13 of *maculiferus* are alike in colouring, and are larger and are part of a lot from the Recherche group, *maculiferus* becomes a synonym of *rhodostomus.*

Some hundreds of shells were collected at Esperance crawling on grass and bushes after rain, and these are quite constant, although the streaks vary in number, the colouring is pale, and none is dark as the island forms, and this is here described as a distinct species.

Bothriembryon esperantia sp. nov.

Plate II., fig. 8.

Shell plumply elongate, not as broad as *bulla,* with less sculpture, the spire conical as long as the aperture, whorls rounded, the columella reflected over the umbilicus but still leaving a notable chink, shell solid. Coloration greyish white sparsely flamed with irregular streaks of dull pinkish brown, the ground colour dominating the coloration. Apex finely punctate, a little more elevated than that of typical *melo,* the adult sculpture rough, irregular radial growth ridges with very little cross sculpture and no decussation notable in some cases: in other rather coarsely granulose as the one described and figured by Pilsbry (p. 6, pl. I., fig. 14) which is here refigured, the form and coloration being diagnostic. Length 23 mm., breadth 15 mm. The largest measures 26 mm. by 16 mm.

Bothriembryon balteolus sp. nov.

Plate II., fig. 9.

Many shells from the Esperance Mallee Belt district, 50 miles south of Norseman, Madura, Salmon Gums, are all dead and agree in showing a strong banded coloration.

In form the shells recall *bulla,* but the spire is not so exsert and they must be near to *rhodostomus* geographically. The shells have the spire definitely less elate than the Esperance coastal species, with the sculpture more regular almost producing a cancellation on the penultimate whorl and shoulder of the last whorl. The ground colour is chalky-white with a narrow purple peripheral band and a large purple circumbilical patch. The columella is

reflected almost covering up the umbilicus, the outer lip thin, and a glaze connects the inner lip to the outer lip across the body whorl. The apex is eroded but shows the coarse pitting of the *melo* series. Measurements—length 21 mm., breadth 15 mm. (Esperance Mallee Belt). The range of this form inland would be interesting, as we might get intermediate localities between this and the Centralian *spenceri*. From Newman Rocks shells are a little more globose, spire shorter, and the colours reversed, being pale brown with a peripheral white band recalling *castaneus*, but differing in sculpture. Bednall (Trans. Roy. Soc. South Austr., Vol. XVI., p. 66, Dec., 1892), recorded *Bulimus melo* Q. & G. from the Fraser Range, from dead shells alone: this report may refer to specimens of this species.

Bothriembryon serpentinus sp. nov.

Plate II., fig. 10.

A large series of shells collected alive by Mr. L. Glauert at Serpentine Falls, Darling Range, all agree in form and coloration though varying a little in proportions. Thus some are shorter recalling the coastal *bulla*, and others are elongate similar to *indutus*, but very unlike in shell texture. These are thin and are pale brownish-yellow thickly longitudinally streaked, being thus referable to the *bulla* style rather than to the *indutus* series. The apex is finely punctate the succeeding whorls rounded, the spire about equal to the mouth, four adult whorls succeeding the two punctate whorls sharply. The columella is reflected, brownish purple, leaving a very small umbilical fissure, the outer lip thin, the aperture brown within. Sculpture, rough closely set irregular radials overrun by concentric lines, almost forming a distinct cancellation on the earlier whorls. A couple picked at random give measurements—length 25 mm., breadth 16 mm., and length 32 mm., breadth 16 mm. The shell figured (type) measures 28 mm. in length and 16 mm. in breadth. The locality falls into the 30-inch annual rainfall belt.

Bothriembryon praecelsus sp. nov.

Plate II., fig. 11.

One specimen from Kellerberrin may be immature, but it is large and very distinct from any shell from the Darling Ranges or the Perth district. The locality is inward of the ranges, and lies in the 10-15 inches rainfall belt.

The shell is inflated but the spire is conical and short, the aperture a little longer than the spire and open, shell very thin. Coloration almost uniform being brown, growth lines lighter. The apex is worn but shows a flattened two whorls stopping suddenly so that almost a varix appears: there is a reticulate pitting now seen. The adult sculpture consists of fine radials crossed by fine concentric lines almost cutting the radials into lozenges, these vanishing below the shoulder on the last whorl, only the rather rude radials persisting. The columella is white, reflected, almost concealing the umbilicus, a very slight glaze crossing to the edge of the outer lip which is thin. The measurements read—length 29 mm., breadth 20 mm., length of aperture 17 mm., breadth of aperture 10 mm.

Bothriembryon sedgwicki sp. nov.

Plate II., fig. 12.

Shell small, spire conical, shorter than aperture, body whorl swollen, umbilicate, but only slight chink remains, shell thin. Coloration brown marked with irregular longitudinal streaks of dirty white which are the

elevated radial ribbing. Apex typical of the *bulla* style, finely punctate, adult sculpture of rough radials, cut by concentric lines forming a subnodulose sculpture, the concentric lines disappearing on the base of the last whorl. Height 17 mm., breadth 11 mm.

Mr. E. Sedgwick, who collected this interesting form at Nangeenan via Merredin, sent a series including juveniles, which are merely the apical whorls, punctate, horny, umbilicate; the next stage shows the adult sculpture forming, succeeding a slight but distinct varix, and at this stage capable of making a perfect epiphragm. On the next whorl the concentric lines appear to be bearing fringes, but these are absent in the adult.

Bothriembryon bulla Menke 1843.

Plate II., fig. 13.

1843—*Bulimus bulla* Menke, Moll. Nov. Holl. Spec., p. 7, April. Darling Range, West Australia.

1844—*Bulimus bulla* Menke, Zeitschr. für Malak. (Menke), 1844, p. 57, April 10.

1848—*Bulimus rhodostoma* Reeve, Conch. Icon., Vol. V., pl. xlix., sp. 323. Nov. New Holland.

1854—*Bulimus baconi* Benson, Ann. Mag. Nat. Hist., Ser. 2, Vol. XIII., p. 99, Feb. 1. Darling Range, West Australia.
Fig'd. Cox, Mon. Austr. Land Shells, p. 73, pl. xix., fig. 13, May, 1868, from a painting of the type by Angas. Refig'd. Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 95, pl. vii., fig. 32, June, 1894 (type).

1892—*Liparus inflatus* var. *bulla* Hedley, Rec. Austr. Mus., Vol. II., p. 29, August.

1892—*Liparus inflatus* var. *rhodostoma* id. ib.

1892—*Liparus baconi* id. ib.

1900—*Bothriembryon inflatus* var. *conispira* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XIII., p. 6, pl. 1, figs. 15-17; apex, fig'd. pl. 4, figs. 71-72, April 23. "King George's Sound, W.A." error = Perth.

1900—*Bothriembryon bulla* id. ib., p. 15.

1900—*Bothriembryon baconi* id. ib., p. 16, pl. 2, fig. 42.

1901—*Bothriembryon baconi* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. 13, Theil 2, heft CLXV., lief. 463, p. 770, pl. 112, fig. 18; pl. 116, fig. 6, sheet dated 8-7-1901.

1901—*Bothriembryon bulla* id. ib., heft CLXVIII., lief. 467, p. 777, pl. 113, figs. 15-16, sheet dated 10-7-1901.

1901—*Bothriembryon rhodostoma* id. ib., p. 786, pl. 114, fig. 6, sheet dated 28-7-1901.

1902—*Bothriembryon durus* id. ib. heft CLXXIII., lief 473. p. 930, pl. 131, figs. 1-2, sheet dated 8-4-1902. Probably Australia.

Shell elongate, plump, spire conical, short, last whorl plump, not obese, shell thin, whorls rather flattened, last whorl very large, mouth broad oval, elongate, outer lip thin, columella straight, reflected, hiding umbilicus which however, still remains open but narrow. Coloration somewhat varied, a greenish appearance prevailing: the background pale green finely streaked with reddish brown and a pale peripheral band overrun however by the streaking: sometimes the green prevails and there is almost a uniform shell but this is rare. At others the red is predominant and the shell takes on a

reddish tone, but always the coloration is characteristic. The apex is punctate, the thimbling finer than in the southern *melo*: the longitudinal irregular ribbing is cut into nodules by the concentric lining and there is commonly a notable deep line just below the suture which is never seen in *melo*, the sculpture being much more pronounced in this species. Some specimens elongate with age and thus we get Reeve's "*rhodostoma*" and Pilsbry's *conispira*. The normal shell measures 25 mm. in length by 16.5 mm. in breadth, *conispira* being 25 by 14.5 mm., and others up to 28 mm. by 16.5 mm.

Bothriembryon bradshawi sp. nov.

Plate II., fig. 14.

A good series, collected by Mr. F. R. Bradshaw at Tambellup, north of the Stirling Ranges, and south of Broome Hill, provides an interesting problem.

The shell is small, thin, spire and mouth about equal in length, spire conical, mouth a little inflated so that it appears somewhat intermediate between the *kingii* and *melo* series.

The apex is a little more elevated than in the *melo* form, but not so elate as in the *kingii* group, and is finely punctate, the sculpture fading away so that no varix-like division is seen. The adult sculpture consists of fine sloping radials being more rude as the shell develops, and continuing on to the base of the last whorl. On the first adult whorl a few widely spaced concentric lines are seen which soon vanish. The early coloration is whitish mottled with reddish brown, the mottlings massing so that the coloration of the last whorl resembles that of some of the well-colored forms of *kingii*.

Length, 19.5 mm., breadth, 12 mm.

Bothriembryon irvineanus sp. nov.

Plate II., fig. 15.

A series, collected by Mrs. Irvine, a very well-known West Australian shell lover, at Cape Naturaliste, along with *B. naturalistarum*, but probably occupying a distinct station ecologically, is here named.

The shell is thin, elongate, of the *melo* form, but narrower and showing no perforation, recalling *serpentinus*, but broader, the spire a little shorter than the aperture, columella twisted. Coloration uniform with no red circumbilical patch. The apex is coarsely punctate recalling that of *kingii*, but broader, more elevated than that of *bulla;* adult whorl strongly rudely radially ribbed crossed by concentric ditches producing a strong subnodulose effect, the radials persisting strongly on to the body whorl but concentric ditches disappear on base. Length of type, 26 mm.: breadth, 16 mm.

Bothriembryon richeanus sp. nov.

Plate II., fig. 16.

A series labelled "Cape Riche, King George's Sound, S.W. Australia" by Brazier, proves that the locality "King George's Sound" was used for the whole of that south-west block, as Cape Riche is sixty miles distant, and is a well known landmark.

The shells are quite distinct, being strongly granulose recalling *leeuwinensis* and *brazieri*, but are narrower than the former, and broader than the latter. They belong to the *kingii* series, but are broader with the

spire not attenuate and about the length of the aperture. The apical whorls are strongly punctate, the adult whorls rounded, the sculpture being rather strongly nodulose, the nodules irregular, but squarish, and persisting but weakening on to the base of the body whorl. The shell is thin and consequently the outer lip is thin, the columella reflected, leaving so minute a chink that the shell appears imperforate. The coloration is a dirty fawn with indistinct longitudinal streakings of dull red; the red circumbilical patch is only seen in one specimen. The type measures 24 mm. in length, 13 mm. in breadth, the aperture 12 mm.

Bothriembryon leeuwinensis Smith 1894.

Plate II., figs. 17 and 18.

1894—*Bulimus* (*Liparus*) *leeuwinensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 94, pl. VII., fig. 27, June; Cape Leeuwin, South-West Australia.

1900—*Bothriembryon leeuwinensis* Pilsby, Man. Conch. (Tryon), Ser. 2, Vol. XIII., p. 13, pl. 3, fig. 49, Apl. 23.

1901—*Bothriembryon leeuwinensis* Kobelt, Syst. Conch. Cab. (Mart & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2, heft CLXV., lief 463, p. 768, pl. 112, fig. 4 (sheet dated 8 VII. 1901).

Smith's comparison reads: "*B. melo* is a broader and more bulky species, and *B. kingii* is more acuminate above, less granular, and exhibits more coloration both externally and within the aperture. The umbilicus is more closed than in the present species, and is surrounded by a brown zone." The notable feature is the strong granulation and this appears to connect it with the *kingii* series. Mr. A. W. B. Powell, of the Auckland Museum, has given me three specimens collected at Flinder's Bay by Clement L. Wragge, and these are topotypes of the species. The apical features prove it to be referable to the *kingii* series from which at sight it appears very different. The shell is elongate, rather stout, the spire about equal to the aperture, but not attenuate, the whorls appreciably shouldered. The apex is elevated, finely punctate, the punctations separable until the end of two whorls, where a definite small varix can be seen. The adult sculpture consists of coarse granulation, rough separate radials being cut into oblong lozenges by concentric deep irregular lines, the unevenness of the radials giving a nodulose suggestion. This continues on to the upper half of the last whorl, the rough radials alone being observed on the lower half. The columella is white, reflected, but leaving a notable umbilical chink behind; a white glaze connects the inner lip with the outer lip which is thin. The coloration is a uniform creamy white.

The length of the figured shell is 29 mm., the breadth 15 mm. A specimen from Lake Cave, Margaret River, generally agrees but is much narrower, measuring 28 mm. by 13 mm.

Another series from Margaret River is short and broad, recalling the *melo* series, but the apex seems to belong to the *kingii* series. The mouth and aperture are about equal, and the sculpture is similar to that of the above, but much weaker, the concentric lines disappearing on the body whorl. The columella is reflected but leaves an open chink, and the outer lip is thin. The coloration is dirty white with flesh streaks. There appears to be much confusion in the area from Cape Leeuwin to Cape Naturaliste, and for the present this form is being only named subspecifically **Bothriembryon leeuwinensis eventus** subsp. nov.; the type measuring 23 mm. in length by 14 mm. in breadth.

Bothriembryon costulatus Lamarck 1822.

Plate II., fig. 19.

1822—*Helix costulata* Lamarck, Hist. Anim. s. Vert., Vol. VI., pt. 2, p. 122, Apl. as synonym of *inflatus* infra, ex "Daudeb, No. 405," which refers to

1821—*Helix* (*Cochlogena*) *costulata* Férussac, Tabl. Syst. Anim. Moll. Limaçons, p. 58, Jan.; p. 54, June. Nomen nudum. "Le port du Roi George, dans la Nouvelle-Hollande, Péron: la baiè des Chiens-Marins, Gaudicho."

Shark Bay is here selected as type locality.

1822—*Bulimus inflatus* Lamarck, Hist. Anim. s. Vert., Vol. VI., pt. 2, p. 122, Apl. Nouvelle Hollande.

Not *Bulimus inflatus* Olivier, Voy. Othoman, Vol. II., p. 356, 1801.

1838—*Bulimus costulatus* Potiez et Michaud, Galerie des Molusques Mus. Douai, Vol. I., p. 138, pl. XII., figs. 17-18, October, ex *Cochlogena costulata* Férussac.

1841—*Bulimus inflatus* Delessert, Recueil Coq. Lamarck, pl. 28, fig. 1. Lamarck's shell figured.

1864—*Bulimus onslowi* Cox, Cat. Austr. Land Shells, p. 24. Dirk Hartog I., West Australia (Onslow).

Figs. Cox, Mon. Austr. Land Shells, p. 74, pl. XIII., f. 13, May, 1868.

1892—*Liparus onslowi* Hedley, Rec. Austr. Mus., Vol. II., 29, Aug.

1894—*Bulimus* (*Liparus*) *onslowi* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 95, pl. VII., fig. 28 (not fig. 29), June. Dirk Hartog Island, West Australia (J. J. Walker).

1900 *Bothriembryon onslowi* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 11, pl. IV., figs. 43, 44, 48; Apex, pl. IV., fig. 75, Apl. 23.

1901—*Bothriembryon onslowi* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2, lief 463, p. 769, pl. 112, fig. 15-16, (p. 765 dated 8 VII. 1901).

The identity of Lamarck's species seems to be obvious though hitherto overlooked. His description reads: "B. testâ ovatâ, ventricosâ, perforatâ, longitudinaliter striatâ, squalide albâ; spira obtusiuscalâ; labro margine subreflexo. Habite dans la Nouvelle Hollande. Mon cabinet. Longueur, près d'un pouce."

This agrees very well with the Shark Bay shell, the words "ventricosâ . . squalide albâ . . spira obtusiuscula" being characteristic of that form. Férussac had previously named the shell *costulatus*, and Lamarck rejected this, renaming it *inflatus*, but unfortunately the latter had been previously used by Olivier, so that Férussac's name comes into use. As localities Férussac gave King George's Sound and Sharks Bay, and though the former locality has been accepted for Lamarck's *inflatus*, the figure given by Delessert is of the Shark Bay shell. This figure measures 27 mm. by 17 mm., and Shark Bay shells vary from 26 to 28 mm. by 17 mm., smaller ones 24 mm. by 16 mm., and 21 mm. by 15 mm. Smith's figure of *onslowi* measures 24 mm. by 16 mm., and Cox's measurements of *onslowi* are equal to 21.2 mm. by 15 mm.

Péron records from Bernier (and other) island(s) in Shark Bay: "Two species of land shells extremely numerous, but all dead, occupied great

stretches of the interior of the island; one was a small species of *Helix*, the other belonged to the genus *Bulimus* of M. de Lamarck." Férussac gave as the collector of his Shark Bay shells, "Gaudicho"; this refers to C. Gaudichaud, the apothecary on the Uranie, which visited Shark Bay in 1818.

In further confirmation, Potiez and Michaud are cited, as they figured the Shark Bay shell under the name *Bulimus costulatus* Férussac, and acknowledged the assistance of Férussac.

The shell is roundly oval, the spire short, obtuse, less in length than the aperture, which is oval, outer lip thin, rather solid. The coloration of all the dead shells seen is white, but the living shell is orange, longitudinally flamed with dull streaks.

Apex flattened not distinguished finally from adult whorls, the sculpture beginning as faint wrinkled lines, the succeeding whorls sculptured with fine concentric lines cutting the faint growth lines into small lozenges which vanish below the periphery of the last whorl. Columella short, reflected triangularly over the umbilicus, which however is not closed.

Bothriembryon minor Pilsbry 1900.

Plate II., fig. 20.

1900—*Bothriembryon onslowi* var. *minor* Pilsbry, Man. Conch. (Tryon), 2nd Ser., Vol. XIII., p. 12, Apl. 23, for Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 95, pl. VII., fig. 29, June. Dirk Hartog I., West Australia (J. J. Walker).

1901—*Bothriembryon melo* var. *hartogensis* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. 13, Theil 2, p. 770, pl. 112, fig. 15, dated June 19. Dirk Hartog's I., W.A.

Smith wrote: "*onslowi* . . . . Five other examples are considerably smaller, averaging only 15 to 18 mm. in length. They are a trifle less globose, and more strongly granular just below the suture." Pilsbry commented: "Apparently adult specimens of this small form before me are even smaller than the dimensions given by M. Smith, two measuring: Alt. 13.5 diam. 9, longest axis of aperture 8 mill, whorls 4½; and alt. 14.5, diam. 8.2, longest axis of aperture 8 mill., whorls a trifle over 5. They are strongly granose below the suture, and striped longitudinally with pale reddish or grey and opaque white." Kobelt later also named this form, and it seems common and easily separable and not a dwarf of "*onslowi.*" Collecting might solve the problem as there is no similar instance of dwarfing in this family.

Bothriembryon whitleyi sp. nov.

Plate II., fig. 21.

A nice series, collected by my colleague, Mr. G. P. Whitley, at Geraldton, is composed of white dead shells. They are, however, quite fresh and do not appear to have been coloured. Shell small, dead white rather shining subglobose perforate, perforation hidden by reflected columella. Apex of two whorls, finely punctate, a subvarix separating these from the adult four whorls which are longitudinally radially wrinkled, the radials crossed by concentric lines, which produce a subnodulose appearance, the base of the last whorl smooth. The mouth is oval, the outer lip thin, the columella rather broadly reflected, hiding the umbilicus, but leaving it quite open. Height 16 mm., breadth 12.5 mm. This is a plumper shell than *minor*, and differs in coloration.

Bothriembryon perobesus sp. nov.

Plate II., fig. 22.

One specimen from the mouth of the Moore River obviously belongs to the *"onslowi"* series, but is even more globose than the most inflated typical *"onslowi."* It is a live shell, and has the same style of coloration as the *onslowi* forms, but in the living shell the ground colour is pale yellowish green, the longitudinal banding a rich brown. The shell is stout, the spire very short and somewhat flattened, the body whorl taking up the bulk of the shell which consists of four adult whorls and two apical whorls, the latter being somewhat strongly eroded. The columella is broad, white, strongly reflected, hiding the narrow umbilicus, which, however, still remains open. Only a slight subcancellate scuplture appears below the suture, the shell otherwise being smooth, the growth lines scarcely showing up. The height of the shell is 25 mm. while its breadth is 19 mm. the length of the aperture being 15 mm., its bread 8 mm. The annual rainfall is between 15 and 20 inches.

Bothriembryon indutus Menke 1843.

Plate II., fig. 23.

1842—*Bulimus indutus* Menke, Moll. Nov. Holl. Spec., p. 6, Apl. Darling Range and Mt. Eliza, West Australia.
Fig'd. Cox, Mon. Austr. Land Shells, p. 73, pl. 13, fig. 10, May, 1868. Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 13, pl. 3, figs. 58-61, Apl. 23, 1900. Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth XIII., Theil 2, heft CLXVIII., lief. 467, p. 783, pl. 114, figs. 2, 3, 7, sheet dated 28-XII.-1907.

1877—*Bulimus ponsonbii* Angas, Proc. Zool. Soc. (Lond.,) 1877, p. 70, pl. xxvi., fig. 1. Western Australia (J. Gould).

1901—*Panda ? ponsonbyi* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed Kuster, Bd. I., Abth. XIII., Theil 2, heft CLXVIII., lief. 467, p. 785, pl. 114, fig. 5, sheet dated 28-VII.-1901. Angas, figure copied.

Although this species is one of the most distinct it was overlooked for some time but is now well known from its form and coloring as well as size. Two notable colour variations occur dull greenish yellow with dark growth period stop marks, and reddish brown with pale yellow growth period stop marks. Apparently these shells stop growth, and the inside of the outer lip takes on a different colouring, and when the shell restarts, it leaves a very distinct contrasting record of the stoppage. The shell is very elongate, stout, regularly narrowed about twice as long as broad, and while the columella is twisted a slight umbilical chink is present, the spire about equalling the aperture in length. The apex is punctate but usually eroded, and no varix can be seen, the adult whorls show a faint nodulose reticulation on upper whorls, the last whorl only with obscure growth marks.

The specimen figured is from King's Park, Perth, and measures 40 mm. in length by 19 mm. in breadth, while smaller ones measure 34 mm. by 16 mm. The dead shells are white as the coloration lies in the rather thick periostracum which clothes the shell.

Hedley (Proc. Malac. Soc. (Lond.), Vol. I, p. 260, 1895), wrote: "Judging from the figure of *Bulimus Ponsonbii,* and from the travels of its collector, I am disposed to deny that it is a *Liparus,* or that it comes from Western Australia, but hold it rather to be a variety of *Panda atomata* collected in New South Wales." There is now little doubt that Gilbert collected the specimens in the neighbourhood of Perth, and that the name is an absolute synonym of *indutus.*

Bothriembryon glauerti sp. nov.

Plate II., fig. 24.

A very distinct form belonging to the *indutus* series, but easily distinguished by its shape, the very short spire and the swollen body whorl, which is more than two-thirds the bulk of the shell. There is a glossy green periostracum which shows the characteristic "*indutus*" growth stages in darker relief. The apex is elevated, and the incurved earliest portion is coarsely anastomosely wrinkled, a coarse irregular pitting succeeding, with finally a fine wrinkling striae forming; with a strong lens this sculpture can be traced on the body whorl, and more notably on the earlier whorls, subsutural wrinkling being present. The columella is twisted, white, a white glaze crossing the body whorl, the aperture within being bluish white, the outer lip thin; there is no umbilical fissure left, the shell appearing imperforate though in the very juvenile stage a small chink may be noted. The type measures 38 mm. in length by 22 mm. in breadth, the length of the body whorl being 30 mm. and that of the aperture 21 mm. The locality is Stirling Ranges, which is included in the 20 to 25 inches annual rainfall belt.

Bothriembryon fuscus Thiele 1930.

Plate II., fig. 25.

1930—*Bothriembryon fuscus* Thiele, die Fauna Süd-West Australiens, Bd. V., lief 8, p. 588, pl. IV., fig. 68. Torbay, South-West Australia.

Thiele described a very immature specimen which appears to be a representative of a very large series collected by Mr. Sidney W. Jackson many years ago in the karri forests at Nornalup Inlet, Deep River, which has a rainfall of 35 to 40 inches annually, which is the same as at Torbay. The Denmark shells are here described, and if these should be later proven distinct, as Thiele's figure is not exactly agreeable they may be called *franki* suggested by Mr. Jackson.

Shell large, elongate, narrow, spire and aperture about equal, latter oval, columella slightly thickened, appressed, commonly closing umbilicus. but very rarely this may be retained as a chink. Coloration varying from straw to dark brownish yellow, streaked with darker brown, especially along the growth lines. Sometimes the juveniles are uniform straw, at others dark chocolate; again shells may be found bearing a broad dark band above the periphery, a form of coloration seen in the shells from the Recherche Archipelago, forms of *rhodostomus*. When the shell rests the outer lip edge is darkened and this provides the dark growth streaking, a feature of all the *indutus* series. The apex is elevated, minutely wrinkling sculptured, the wrinkles fading into growth ridges, the whorls showing no distinct separation but succeeded by a fine concentric lining which never becomes prominent and soon disappears. The growth lines are flattened so that they are more notable as colour streaks than ridges, and the faint concentric lines can only be seen with a lens, the body whorl appearing smooth. Length (type of *franki*) 40 mm., breadth 21 mm., length of aperture 20 mm. These shells are found in hazel scrub up high on hazel trees and leaves, up to 40 feet on the limbs.

Bothriembryon kingii Gray 1825.

Plate II., figs. 26-28.

1825—*Bulimus kingii* Gray, Annals Philos (Thomson), Vol. XXV., (2 Ser., Vol. IX.), p. 414, June. New Holland (Capt. King) = King George's Sound, South-West Australia.

1826—*Helix bulimus* King, Narr. Surv. Coasts Austr., Vol. I., p. 12, "1827" Apl. 15, 1826. Near Bald Head, King George's Sound.

1828—*Helix kingii* Wood, Suppl. Index Test, p. 22, pl. 7, Helix, fig. 27, (pref. May 17), New Holland. Brit. Mus. Type figured.

1822—*Helix trilineata* Quoy & Gaimard, Voy. Astrol., Zool., Vol. II., p. 107, pl. IX., figs. 1-3. Bald Head, King George's Sound, S.W.A.

1848—*Bulimus trilineatus* Reeve, Conch. Icon., Vol. V., pl. XLVIII, sp. & f. 310, November, as of Q. & G. New Holland.

1849—*Bulimus trilineatus* Reeve, Conch. Icon., Vol. V., pl. LIX., sp. & f. 397, January, ex Q. & G. "Port George," New Holland.

1864—(*Bulimus*) *quoyi* Cox, Cat. Austr. Land Shells, p. 23, new name for Reeve's fig. 397, not Reeve's fig. 310.

1868—*Bulimus kingi* Cox, Mon. Austr. Land Shells, p. 75, pl. XIII., fig. 7, May.

1892—*Liparus kingi* & var. *trilineatus* Hedley, Rec. Austr. Mus., Vol. II., p. 29, Aug.

1900—*Bothriembryon kingii* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 7, pl. 2, figs. 21-28, apex, pl. 4, fig. 77-78, Apl. 23.

1900—*Bothriembryon physoides* var. *humilis* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 10, pl. II., figs. 33-34, Apl. 23. King George's Sound, West Australia.

1901—*Bothriembryon trilineatus* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2, heft CLXV., lief. 463, p. 766, pl. 112, figs. 5-9, (sheet dated 8, VII., 1901).

1901—*Bothriembryon kingii* Kobelt, id. ib., heft CLXVIII., lief 467, p. 779, pl. 113, figs. 19-23, pl. 116, figs. 14-15, (sheet dated 10 VII., 1901).

1901—*Bothriembryon physoides* var. *humilis* Kobelt, id. ib., p. 790, pl. 116, figs. 9-10, (sheet dated 2 VIII, 1901).

The typical *kingii* shows the attenuate form of this group, though the shell was only half grown; a little later Quoy and Gaimard gave excellent figures of the shell and animal from exactly the same place as King had collected them. Their shell was fully grown, and less boldly marked, and both names have sometimes been used but the latter name is absolutely synonymous. Unfortunately the general locality, King George's Sound, was used for shells from the surrounding area where more than one race may occur. Hence Pilsbry named a var. *humilis* of *physoides*, which is based on a small local series of the present species, but the name can not be used, as no definite locality is known, and the shells appear immature.

The shell is elongate, the spire acuminate, the apex elevated, the mouth elongate, shorter than the spire, the columella reflected and appressed with a twist, obliterating the umbilicus, outer lip thin. The shell is thin and delicate, and the coloring is a dirty white streaked more or less thickly with pale brown, rarely of a reddish tinge. The streaks are commonly notable as in the type of *kingii*, and are as commonly almost obsolete as in the type of *trilineatus*. Some are almost clear white, others clear yellowish, and in some cases the streaks coalesce, and an almost uniform brown body whorl is formed. The thinness and shape are however constant as is the lack of any defined sculpture, the rude flattened radials showing no cross sculpture. The apex consists of two whorls, the tip elevated, minutely punctate, the punctations finally running into lines: the adult whorls follow without a varix, but the

change can be seen. The columella is reflected, closing the umbilicus as a general rule, but in some cases as in *trilineatus* typical, as here shown, the swelling of the body whorl allows the retention of a slight chink indicating that the juvenile is perforate. A circumbilical red patch is usually present in this group. The two specimens figured are from the type locality, and represent normal *kingii* and *trilineatus*, the former measuring 24 mm in length, by 13 mm. in breadth, the latter being 29 mm. in length, by 15 mm. in breadth.

The type of Pilsbry's var. *humilis* is also here figured, and it measures 17.5 mm. in length, by 10 mm. in breadth. It is obviously referable to this series, but differs from the typical form in showing a coarser longitudinal radial ribbing, cut by a few concentric lines on the earlier whorls and on the shoulder of the last whorl. There is an umbilical chink, and no red circumbilical patch, and somewhat similar shells have been seen from the Pallinup River, South Coast.

Bothriembryon notatus sp. nov.

Plate II., fig. 29.

An excellent series from the Pallinup River, south coast, recalls *B. jacksoni*, but the shells are narrower and have a paler ground colour. Shell thin, elongate, of the *kingii* style, but the spire not so attenuate, and the mouth is equal to the spire in length. Coloration greyish-white longitudinally flamed with red brown, the markings varying in intensity, some showing few marks being almost unicolor, while others have the markings running together so as to produce an almost uniform dark shell. The red circumbilical patch is always present. The apex is of the typical *kingii* form, the succeeding whorls sculptured with wide longitudinal ribbing, which is most pronounced below the suture producing a puckered collar. This persists on to the body whorl, where otherwise the ribbing becomes obsolete. The columella is reflected so as to hide the umbilicus, which, however, remains open as a chink. Length 24 mm., breadth 11 mm., length of aperture 12 mm.

Bothriembryon jacksoni sp. nov.

Plate II., fig. 30.

A very interesting form of the *kingii* series was collected by Mr. Sidney W. Jackson at Deep River, Frankland River, Nornalup, to the west of King George Sound, on trees and shrubs in the hazel scrub among the karri.

It lacks the acuminate spire having a rather swollen body whorl with a conical short spire, the texture thin, the colouring bright fawn with deep red brown streaks, and a deep red brown circumbilical patch. The apex is finely regularly punctate throughout the two whorls, the sculpture on the subsequent whorls being composed of rude radials crossed lightly on the earlier whorls by fine concentric lines forming a fine nodulation at places, but irregular and becoming obsolete on the body whorl. The columella is twisted, white, and reflected leaving an umbilical chink. The length of the type is 27 mm., the breadth 15 mm., length of spire 13 mm.

Bothriembryon maxwelli Kobelt 1901.

Plate II., fig. 31.

1901—"*Bothriembryon*" *maxwelli* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2. heft CLXVIII., lief 467, p. 781, pl. 112, figs. 4, 5, 17, sheet dated 28 VII. 1901, ex Brazier M.S. No definite locality = "Doubtful Island King George's Sound, W.A."

1900—*Bothriembryon kingii* var. *solidus* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 9, pl. II., fig. 28, April 23. West Australia = Margaret River.

Specimens from Cape Freycinet agree so closely in their features with the figure and description of *sayi* that they can be so named, while *solidus* Pilsbry appears to be merely a large local variation of this species.

The typical shell is small, with an attenuate spire with the whorls flattened, rather solid, with the umbilicus always left a little open. The coloration is whitish with a few pale red streaks at times. There is no circumbilical patch in this series, other wise there is no discrepancy at all. A rather notable feature is the thickening of the columella and the strong white glaze connecting the inner and outer lips, the latter having the edge stouter than usual.

The type of *solidus*, here figured, is much larger and more solid, and belongs to a series from the Margaret River, having the same conical attenuate spire with flattened whorls, and the longitudinal sculpture a little stronger.

Bothriembryon naturalistarum Kobelt 1901.

Plate II., figs. 35 and 36.

1901—*Bothriembryon kingii* var. *naturalistarum* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2, heft CLXVIII., lief. 467, p. 781, pl. 113, figs. 22-3, sheet dated 28-VII.-1901. Cape Naturaliste, West Australia.

1900 *Bothriembryon kingii* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 9, pl. 2, fig. 30 only, Apl. 23. Cape Naturaliste, W.A.

Pilsbry wrote: "Fig. 30 is a small specimen from Cape Naturalist. There are 5 whorls, the last inflated below, almost imperforate. It is beautifully streaked with opaque, glossy white on a corneous and purplish brown ground. Alt. 20, diam. 11, longest axis of aperture 10, 7 mill. The aperture is decidedly more oblique than in the typical form from King George Sound. It is not unlikely that this will prove a geographic race or variety. From the Cox collection." Kobelt gave this the varietal name *naturalistarum*. The series from which Pilsbry selected the figured shell is before me, and I am refiguring his specimen. Again it is immature, but numbers collected by Tom Carter at the same locality show that it develops into an elongate shell very like that from Margaret River, which I regard as *sayi*, but it is thin and has the mouth more expanded, is smooth, and measures 25 mm. in length by 13 mm. in breadth.

Local naturalists must study these shells and fix the status of the named forms.

Bothriembryon revectus sp. nov.

Plate II., fig. 37.

While collecting numerously *B. jacksoni* at Deep River and Bow River, Mr. Sydney W. Jackson also found alive under debris on ground in dense hazel scrub at the Bow River some shells of the *kingii* series, but sculptured after the style of *brazieri* and *leeuwinensis*. The narrow shell here selected as type measures 23 mm. in length by 11 mm. in breadth; a broader shell measures 23.5 mm. in length by 12.5 mm. in breadth. The spire about equals the aperture in length, and is not attenuate. The columella is appressed so that barely a chink remains, and there is a red circumbilical patch, while the

1868—*Bulimus kingi* Cox, Mon. Austr. Land Shells, p. 75, pl. 19, fig. 12, 12a, May. Doubtful I., W. Australia (Masters).

1900—*Bothriembryon kingii* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., pl. 2, fig. 29 only, Apl. 23.

Although Cox figured this form he did not mention it in the text, and Pilsbry also figured a specimen which is here refigured, and then Kobelt brought in a Brazier MS. name for this shell. There are many specimens in the Australian Museum bearing Brazier's MS. name, and localised as Doubtful Island, but which Doubtful I. is intended must be found out by local collectors On the labels here it is said to be "Doubtful Island, King George's Sound," and many shells of the *melo* series are also so labelled, one set being the *castaneus* form (Pilsbry's fig. 18), and another set agreeing with Pilsbry's figure 3. If there be three distinct series of *Bothriembryon* living on Doubtful Island, the place is in need of close investigation. The shell is a small thin representative of the *kingii* form, but is smaller, narrower and not so attenuate as the typical shell. It is always of a fawn colour, rarely streaked with reddish and the red circumbilical patch is usually absent. The apex is elevated, normally punctate, the punctations linking up into lines, the adult sculpture easily separated, rough radial ribbing developing below the suture where it persists through growth. The radials become obsolete with age, while a regular series of concentric lines appears on the earlier whorls, none of which cuts the radials. The columella is appressed, almost closing the umbilicus, but generally a chink remains. The length of the figured specimen is 20 mm. with a breadth of 10 mm.

Recent research suggests that this Doubtful Island is the island off Doubtful Island Bay, and this is confirmed by the name *maxwelli* as there is a Mt. Maxwell overlooking that bay.

Bothriembryon perditus sp. nov.

Plate II., fig. 32.

Specimens collected by E. Gratwick, 70 miles east of Israelite Bay, that is, some twenty miles east of the type locality of *gratwicki,* are all dead, but show remains of the colour pattern, which is that of the *kingii* series. The shape is elegant, the body whorl not swollen, but the aperture about equal to the spire, the texture thin, the spire is not acuminate. The coloration shows regular reddish flame streaks on a whitish ground, some however nearly unicolor. Apex elevated, punctate, the succeeding sculpture regular wavy growth lines with transverse cross lining but the whole sculpture very weak: the puckering below the suture is well marked and a little of the longitudinal radials remains on the body whorl. Columella twisted and appressed so that no umbilical fissure remains, the shell appearing imperforate. A thin glaze crosses from the inner lip to the edge of the outer which is thin. Length of type 24 mm., breadth 12 mm.

The locality is in the annual rainfall 15-20 inches belt.

Bothriembryon sayi Pfeiffer 1847.

Plate II., figs. 33 and 34.

1847—*Bulimus sayi* Pfeiffer, Proc. Zool. Soc. (Lond.), 1846, p. 114, Jan. 26, 1847. Locality unknown = Cape Freycinet, West Australia. Fig'd Reeve, Conch. Icon., Vol. V., pl. LXV., sp. and fig. 458, 1849.

apex is of the *kingii* style. The sculpture is subnodulose, the radials irregular and rather ill-defined, while the concentric lines vary in strength, but the sculpture is notable in every case. The coloration is fawn, more or less flamed with red brown, the shell thin and the surface lustreless.

A similar shell was found on small bushes" "in jarrah forest, Mt. Frankland," three months later by Jackson.

Smith's record of *physoides* (Proc. Malac. Soc. (Lond.), Vol. I., p. 95, pl. VII., figs. 30-31, June, 1894) may refer to shells of this form.

Bothriembryon brazieri Angas 1871.

Plate II., fig. 38.

1871—*Bulimus* (*Liparus*) *brazieri* Angas, Proc. Zool. Soc. (Lond.), 1871, p. 19, pl. I., fig. 28, June 12. Sinclair's (error for Stirling) Range, King George's Sound, West Australia.

1873—*Bulimus* (*Liparus*) *brazieri* Brazier, Proc. Zool. Soc. (Lond.), 1872, p. 807, correction of error of locality name.

1892—*Liparus brazieri* Hedley, Rec. Austr. Mus., Vol. II., p. 29, Aug.

1900—*Bothriembryon physoides* var. *brazieri* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XIII., p. 10, pl. 2, figs. 38-40, Apl. 23.

1901—*Bothriembryon brazieri* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2, heft CLXVIII., Lief. 467, p. 778, pl. 113, figs. 17-18, (sheet dated 10, VII, 1901).

This extraordinary development of the *kingii* series is shorter than usual, not so acuminate in the spire, the whorls more rounded. The coloration is a brownish fawn with a few red radial streaks and a bright red circumbilical patch. The sculpture is coarsely granular, the rude longitudinal ribs being cut into nodules by deep concentric lines, and this sculpture continues on to the base of the body whorl. The apex is of the *kingii* style, finely punctate and stopping abruptly at the end of two whorls. The columella is white, appressed leaving a small chink. The shell is thin, and the figured one measures 19 mm. in length by 10 mm. in breadth.

Bothriembryon gratwicki Cox 1899.

Plate II., fig. 39.

1899—*Buliminus gratwicki* Cox, Proc. Linn. Soc., N.S.W., Vol. XXIV., p. 435, fig. in text, December 9. 50 miles East of Israelite Bay, South-West Australia.

1900—*Bothriembryon gratwicki* Pilsbry, Man. Conch. (Tryon), Ser. 2, Vol. XIII., p. 11, pl. 2, figs. 31, 32, pl. 45, figs. 2-4, Apl. 23.

1901 -*Bothriembryon gratwicki* Kobelt, Syst. Conch. Cab., (Mart & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2, heft CLXVIII., lief. 467, p. 789, pl. 116, fig. 718, (sheet dated 2, VIII, 1901).

This interesting shell is elongated, narrow, spire long, pointed, longer than aperture, which is narrowly oval, solid, chalky, umbilicate. The coloration is chalky white. Strongly sculptured throughout, thereby differentiating this species from all others save *brazieri*. The sculpture consists of elevated irregular rounded ribs, apparently intensified growth lines, over-run with concentric lines forming a subnodulose ornament, the nodules irregular in size and form.

The apex is coarsely wrinkly striate around the upper part of the whorls, the lower reticulately pitted, consisting of two full whorls, the adult sculpture abruptly forming thereafter, almost a varix intervening.

The columella is strongly reflected, but does not hide the umbilicus, and joins the outer lip, which is thin, by means of a glaze across the body whorl, almost freeing the mouth.

Length of figured shell, 27 mm.; breadth 12 mm.

The locality is in the annual rainfall 10-15 inches belt.

Bothriembryon dux Pfeiffer 1861.

Plate II., fig. 40.

1861—*Bulimus dux* Pfeiffer, Proc. Zool. Soc. (Lond.), 1861, p. 24, May 1. King George's Sound, South-West Australia. Fig'd. Cox, Mon. Austr. Land Shells, p. 71, pl. XIII., fig. 4, pl. XVIII., fig. 16, May, 1868.

1892—*Liparus dux* Hedley, Rec. Austr. Mus. Vol. II., p. 29, August.

1894—*Bulimus* (*Liparus*) *dux* Smith, Proc. Malac. Soc. (Lond.), Vol. 1, p. 94, June.

1900—*Bothriembryon dux* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 3, pl. 3, fig. 62, Apl. 23.

1901—*Bothriembryon dux* Kobelt, Syst. Conch. Cab., (Mart & Chemn.), ed. Kuster, Bd. I., Theil 2, heft CLXV., lief. 463, p. 763, pl. 112, figs. 1-2, sheet dated 21 : VI. : 1901.

This magnificent species stands alone in its large size, its white colour, and its solidity. The apex is regularly punctate, the sculpture is of rough radials crossed on the earlier whorls by fine concentric lines, the cross sculpture vanishing on the shoulder of the last whorl. The columella is broadly reflected, concealing an open umbilicus, and the outer lip is thin. The spire is about the same length as the aperture. The shell figured measures 60 mm. in length by 35 mm. in breadth. Odd specimens are known from Norseman, Dundas, Salmon Gums, Balladonia, Esperance Mallee Belt, and it thus seems to be an inhabitant of the drier inland belt and not coastal although all the early collected specimens are labelled King George's Sound.

Bothriembryon barretti Iredale 1930.

Plate II., figs. 41 and 42.

1930—*Bothriembryon barretti* Iredale, Vict. Naturalist, Vol. XLVII., p. 119, fig. in text, Nov. Nullarbor Plain, S.W. Australia.

1879—*Bulimus indutus* var. *pallidus* Tate, Trans. Proc. Roy. Soc. Adelaide, South Austr., 1878-9, p. 134. Bunda Plateau, Nullarbor Plain, South Australia.

Not *B. pallidus* C. B. Adams, Proc. Bost. Soc. Nat. Hist., Vol. II., p. 12, 1845.

1900—*Bothriembryon indutus* var. *pallidus* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. XIII., p. 15, pl. 3, figs. 63, 64, 65. Apl. 23.

1901—*Bothriembryon indutus* var. *pallidus* Kobelt, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Theil 2, heft CLXVIII., lief 467, p. 784, pl. 114, fig. 8 (sheet dated 28-VII.-1901). Pilsbry's figures copied only.

The original description of *barretti* reads: "Shell elongate, dirty white, aperture about equal to length of spine (spire). The apex is sculptured with a curious fine wrinkling, which develops into fine radials which are later crossed by revolving lines. This causes a mat-like appearance of rather longitudinal nodules, which, however, disappear upon the base. A young example shows the spiral sculpture much more prominently than in the adult. There is an umbilical chink present, and the outer lip is sharp. Whorls, six; length, 27 mm.; breadth, 15.5 mm.

The type of *B. barretti* was collected near Hampton inside the Western Australian boundary. Tate's locality, "Bunda Plateau" also crosses the border line, and in a series sent to Pilsbry he figured two variations, the general label being "Eucla." Among the shells before me now there are also two varieties, and it is now seen that the coastal shells are narrower than the more inland ones. Upon referring to the rainfall again, that is given as being 20-25 inches on the coast, and only 15-20 inches in the inland area. The narrow form was figured by Pilsbry, f. 63, and his specimen is here refigured as type of a subspecies, **B. b. indictus** nov., the shell measuring 30 mm. in length by 15 mm. in width, the series coming from Eucla.

Bothriembryon distinctus sp. nov.

Plate II., fig. 43.

A series of shells from Cardanumbi, west of Eyre, is of great interest, the shells having an acuminate spire with a swollen body whorl. This shape is not seen in any other series, the *kingii* being elegantly slender, while the *melo* forms are regularly oval.

The coloration is dirty white in the dead shells examined. The apex is not elevated, wrinkled, the wrinkling being succeeded by a punctation, no subvarix visible, the adult sculpture being of the usual rough radials, somewhat subdued, and crossed by fine concentric lines, irregularly forming squarish nodules, which disappear altogether on the body whorl, only faintly discernible on the penultimate one, and never very strong on any of the earlier whorls. Although the umbilicus is open, the broadly reflected columella hides it, the mouth is rather large, the outer lip thin. The spire is longer than the aperture but the body whorl is large and dominant. The length of the type is 27 mm., breadth 15.5 mm., length of the aperture 12 mm., the breadth of the penultimate whorl 9 mm.

The locality is in the annual rainfall 10-15 inches belt, and from the 70-mile tank at Balladonia similar shells have been sent along with *barretti*.

As above stated, this species does not fit into any of the named subgeneric groups so is here differentiated as **Celatembryon** subgen. nov.

FAMILY **LAOMIDAE.**

Though this family name is continued, it may need revision as all the Australian forms have unarmed mouths, and a distinct shell appearance, the Neozelanic typical *Laoma* having teeth in the aperture, and a different shell texture. However our shells appear to be of Paralaomid alliance, and that is a Neozelanic group with suggested relationship to *Laoma*.

Genus **WESTRALAOMA** gen. nov.

Ordinary looking Paralaomids in general appearance, but with the protoconch concentrically spirally striate. The shells are small, generally under 3 mm. in breadth, and 1.50 mm. in height, depressedly conical with

comparatively large apical whorls, the apex, as above, concentrically spirally striate, the adult sculpture radial threads, with larger radial ridges, more or less distant, and usually well marked, rarely with concentric striation. The umbilicus is comparatively wide and open, the mouth circular, the lip thin. The type of *Westralaoma* is *W. experta* nov.

The true *Paralaoma* (Iredale Proc. Malac. Soc. (Lond.), Vol. X., p. 380, Sept., 1913) was based on a similar looking Kermadec shell, which has a smooth or radiately striate protoconch, and which lived in dry places, and the majority of Australian Paralaomids have the same habit.

Westralaoma experta sp. nov.

Plate I., figs. 18 and 28.

1868—*Helix morti* Cox, Mon. Austr. Land Shells, p. 21, pl. XI., fig. 13, W. Australia.

1894—*Patula morti* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 87, June; above record only.

When Smith included this species on Cox's record, he noted "This is the only instance among the Australian Helices in which the same species occurs on both sides of the continent," as it had been described from Sydney. Once again geographical values prove more important than superficial association, as upon re-examination, the Westralian shells are seen to differ in the essential feature of the sculpture of the protoconch. The series so named by Cox is available and the species is named as above. Shell very small, subconical, narrowly umbilicate, brown. The apex is large, bulbous, of two whorls, spirally finely striate, adult whorls sculptured with distant radial ridges and fine striae, on the last whorl the strong radials number between thirty and forty, the interstices finely radially striate with a finer concentric striation, forming a subreticulation under a high power; the mouth is large, the outer lip thin. Breadth 1.25 mm.; height .5 mm. The type locality is King George's Sound, collected by Masters.

Westralaoma scitula sp. nov.

Plate I., fig. 19.

This species, discovered by Mr. Sidney W. Jackson at the Bow River, South Coast, is somewhat depressed, the umbilicus open, deep, and about one-third of the basal breadth.

The apical whorls are finely concentrically striate without any varix, the adult sculpture being composed of fine radial striae, with about twenty to twenty-five developing into prominent ridges, about six to eight striae between each ridge. The whorls are convex, the last whorl subangulately rounded, but not keeled, the mouth open subcircular, lip thin, columella straight, a little reflected, not obscuring the umbilicus in any way.

Breadth 1.5 mm.; height .6 mm.

Found in Hazel and Karri scrub under debris on ground.

Westralaoma expicta sp. nov.

Plate III., fig. 4.

A typical Paralaomid form with the apex elevated, superficially smooth but, with a strong power, concentric lining can be recognised: adult sculpture of the regular Paralaomid style, fine radials with distant coarse ridges about

twenty-five, the fine radials crossed by fine concentric threads suggesting a faint decussation which is faintly seen on base. The umbilicus narrow deep, about one-fourth the breadth of the base, the mouth descending, subcircular, outer lip thin, columella slanting, reflected. Breadth 1.5 mm; height 1 mm.

Nangeenan via Merredin, W.A., collected by E. Sedgwick.

Westralaoma aprica sp. nov.

Plate III., fig. 7.

A depressed Paralaomid form lacking strong radial ridges, and the fine radials are crossed by a subordinate concentric threading producing a finely decussate appearance which is more notable in the umbilical cavity, which is about one-third the breadth of the base. Shell subdiscoidal, spire little elevated, apex finely concentrically striate, mouth subcircular, outer lip thin, columella a little reflected. Breadth 2 mm.; height 1.1 mm.

Nangeenan via Merredin, W.A., collected by E. Sedgwick.

Genus **INSULLAOMA** Iredale 1937.

1937—*Insullaoma* Iredale, South Austr. Naturalist, Vol. XVIII., p. 19, Sept. 30. Haplotype *Paralaoma riddlei* Iredale.

This name was introduced subgenerically for the South Australian forms of *Paralooma*, as these had the apical whorls spirally striate or even lirate, whereas the typical form had the apex smooth or radially finely striate. The shell selected as type of *Insullaoma, riddlei,* was somewhat elevated, umbilicus narrow, finely reticulately sculptured, and had the apex boldly strongly concentrically lined. Of course this cannot be seen without a strong lens. Moreover, in this case there was a peripheral subkeeling. The recognition of a Western Australian form agreeing in all these features has led to the admission of this group generically.

Insullaoma predicta sp. nov.

Plate I., fig. 22.

Another of the discoveries of Mr. Sidney W. Jackson at Bow River, South Coast, especially as it appears to be a true *Insullaoma.* Shell small, subdiscoidal, spire short, brown, umbilicus narrow. The apical two whorls are large and bulbous, and are coarsely spirally lirate: the adult whorls are closely fine radiate, with a fine concentric striation crossing it, the last whorl subkeeled. The mouth is subcircular, outer lip thin, columella a little reflected, the umbilicus open, narrow, less than one-third the width of the base. Breadth 1.25 mm.: height .6 mm.

Found alive under karri bark at foot of karri tree on edge of wattle scrub.

Genus **GRATILAOMA** gen. nov.

Type **G. cara** sp. nov.

Plate I., fig. 20.

This beautiful little shell collected by Mr. Sidney W. Jackson at the Bow River, South Coast, suggests an elevated relation of *Westralaoma,* as it is subconical with similar radials, but has a cross sculpture of crosslining, the umbilicus being narrowed.

As *Westralaoma* is constant in form it seems better to name the present form separately than refer it to that genus, and thus spoil the homogeneity of the group.

Shell very small, subconical, whorls a little rounded, sutures lightly impressed, last whorl descending rather rapidly, mouth subcircular, oblique, outer lip thin, columella rather broadly reflected, obscuring a little the narrow open deep umbilicus. Coloration pale brownish. Apex very finely concentrically striate, about two whorls, adult whorls three and a half, sculpture with fine growth striae and these are crossed by very obscure concentric striation. A few distant large striae develop but they can scarcely be called ridges; these number about twenty-five to thirty but they are irregularly spaced and never prominent. Breadth 1 mm.: height .8 mm.

Found alive under karri bark in dense wattle scrub.

FAMILY **DIPNELICIDAE.**

This family was introduced for an interesting shell from Hammock Island, South Australia, and it was remarked "It has not yet been discovered on the mainland, which suggests that it is a relict form of great age." Mr. Sidney W. Jackson collected, at the Bow River and Deep River, specimens of another curious shell, and though it differs in detail it seems to recall the South Australian shell in some respects. It apparently does not fit into any of the other families, such as Charopidae, Laomidae, Flammulinidae or Rhytididae.

Genus **ANNOSELIX** gen. nov.

Type **A. dolosa** sp. nov.

Plate I., figs. 24 and 27.

A very curious little shell, regularly broadly conical, the base convex, the periphery keeled, umbilicus deep, very narrow, the mouth squarish, the outer lip thin, columella.

Coloration brown, base paler brown, but sometimes flamed with reddish brown.

One apical whorl apparently smooth but obscurely radially striate, the striae developing on the adult whorls without any intervening varix. There are four and one-half adult whorls regularly increasing, whorls flattened, sutures scarcely impressed. The radial striae develop slowly and become very numerous and fine, while a delicate concentric striation also forms, producing a very fine semi-cancellate appearance. On the base the concentric spirals generally predominate. Breadth, 7.5 mm.: height 5 mm.

The type is from Deep River, and some specimens from Bow River, South Coast, show that, in some cases, the radials, every now and then, strengthen into ridges and create a fringe at the periphery and continue strongly on to the base. This fringe sticks out a little, and presents a saw-like appearance to the peripheral keel.

FAMILY **CHAROPIDAE.**

This family has a few members in Western Australia, but there may be many more, as they are minute and difficult to find. Seven species have been described and while one is rejected, a few are added. One eastern genus, *Pernagera,* based however on a western shell, is admitted, but the remainder of the species appear to be of endemic origin. All the species so far seen have no armature of the mouth, and all are openly umbilicate. The features of the family are the small size of the shell, the depressed helicoid form, commonly discoidal, with an adult sculpture of numerous radial ridges of varying strength.

Genus **PERNAGERA** Iredale 1933.

1933—*Pernagera* Iredale, Rec. Austr. Mus., Vol. XIX., p. 53, Aug. 2. Orthotype *Helix albanensis* Cox.

Shell small, somewhat elevated for this family with a very wide cavernous umbilicus, the radial sculpture being rather coarse. Whorls loosely coiled, sutures deep, almost canaliculate, apex radially striate, the tip smooth. The mouth is subcircular, outer lip thin, columella straight, scarcely reflected at all.

Pernagera albanensis Cox 1868.

Plate I., fig. 23.

1868—*Helix albanensis* Cox, Proc. Zool. Soc. (Lond.), 1867, p. 723, April 3. King George's Sound, West Australia (Masters). Fig'd. Cox, Mon. Austr. Land Shells, p. 15, pl. IV., fig. 2, May, 1868.

Shell small, almost subglobose, spire conical, whorls rounded, loosely coiled, almost separated by a canaliculate suture, the last whorl descending, other characters as for the genus. Coloration fawn, irregularly rayed with reddish. Apex tip smooth, then radiately striate, the striae developing into riblets which are numerous and fairly regularly spaced, about seventy-five on last whorl, the interstices finely radially striate, no concentric lines apparent. Umbilicus funnel shaped, about one-half the width of the shell. Breadth 5 mm.; height 3 mm.

Pernagera lena sp. nov.

Plate III., fig. 3.

A very pretty little shell, collected by Mr. Sidney W. Jackson at the Bow River, recalls *albanensis* in miniature. Shell small, subdepressed, spire slightly elevated, whorls rounded, sutures deep, almost canaliculate, last whorl descending a little, mouth subcircular, columella straight, scarcely reflected, umbilicus wide, funnel shaped exposing all the whorls. Coloration pale brownish with broad red flames. Apex smooth at tip, then finely radially striate, the striae developing into ridges which are regular and numerous, numbering about one hundred and twenty on the last whorl, the interstices striate. Umbilicus about half the width of the base of the shell. Breadth 3 mm.; height 1.5 mm. Under bark and leaves on the ground in Hazel scrub.

Genus **LUINODISCUS** Iredale 1937.

1937—*Luinodiscus* Iredale, Austr. Zool., Vol. VIII., p. 331, Mch. 12. Orthotype *Helix cuprea* Cox.

"Small flattened charopid shells, spire not sunken, umbilicus wide, mouth small, thin, sculpture of regular fine radials, protoconch spirally lirate." While the type of *Luinodiscus* is a small shell, other species, referred for the present to this group, are large and more bulky.

Luinodiscus cupreus Cox 1868.

Plate III., fig. 5.

1868—*Helix cuprea* Cox, Mon. Austr. Land Shells, p. 22, pl. XII., fig. 9, May. King George's Sound, West Australia (Masters, A. M.).

1875—*Helix* (*Charopa*) *nupera* Brazier, Proc. Linn. Soc., N.S.W., Vol. I., p. 18, Apl. 27. King George's Sound, W.A. (Masters).

Shell discoidal, spire not sunken, whorls rounded, sutures deeply impressed, last whorl descending a little, mouth subcircular, lip thin, columella not reflected, straight, umbilicus very wide. The apex is concentrically striate, the adult whorls closely finely ribbed, ribs about eighty in number, interstices striate. Coloration fawn. Breadth 2.5 mm.; height 1.5 mm.

Luinodiscus sublestus Benson 1853.

1853—*Helix sublesta* Benson, Ann. Mag. Nat. Hist., Ser. 2, Vol. VI., p. 30, Jan. 1. Freemantle, Swan River, West Australia.
Fig'd. Reeve, Conch. Icon., Vol. VI., pl. 174, sp. 1177, Oct. 1853.
Fig'd. Cox, Mon. Austr. Land Shells, p. 16, pl. XI., fig. 10, May, 1868.
1930—*Charopa hedleyi* Thiele, Die Fauna Südwest Austr., Bd. V., lief 8, p. 587, pl. IV., fig. 67. Brunswick.

Benson naturally gave no details as to the protoconch features nor the number of ribs. It was differentiated from "*H. Iuloidea,* Forbes, by its narrower umbilicus, and the want of concavity in the spire; from *H. cygnea* by the first mentioned feature, and the sculpture."

Thiele does not compare his new species with this, and generally there is agreement, the protoconch being described as spirally sculptured, its size being given at 3.75 mm. in breadth, 1.8 mm. in height, with the umbilicus 1 mm. wide.

Benson's description is here given as the species needs fixation: "Shell rather broadly umbilicate, orbiculately depressed, above red horny, below horny, very minutely costulately striate above, rather flattened, sutures impressed, whorls four, the last a little depressed, rounded, aperture vertical, roundly lurate, peristome acute, umbilicus perspective. Diam. major 3, minor 2½, axis 1 mill."

Specimens from the Swan River, collected by R. Helms, measure up to 4 mm. in breadth by 2 mm. in height. These generally agree that the spire is flattened, but not depressed, the umbilicus wide, open, perspective, fully one-third the width of the base. The apex appears to be smooth but under a high power is seen to be finely concentrically striate, the adult sculpture of radial ridges shows between ninety and one hundred on the last whorl, the intestices being crossed by very fine concentric threads, only discernible by a high power.

Specimens from Peppermint Grove are consistently smaller but otherwise there appears to be no definable distinction.

Luinodiscus cygneus Benson 1853.

Plate I., fig. 25.

1853—*Helix cygnea* Benson, Ann. Mag. Nat. Hist., Ser. 2, Vol. VI., p. 30, Jan. 1. Perth, Swan River, West Australia (Dr. J. F. Bacon).
Fig'd. Reeve, Conch. Icon., Vol., VII., pl. 174, sp. 1182, Oct. 1853.
Fig'd. Cox, Mon. Austr. Land Shells, p. 16, pl. 12, fig. 3, May, 1868.
1930 *Charopa cuprea* Thiele, Die Fauna Sudwest Austr., Bd. V., lief 8, p. 587. Fremantle, S.W.A.
Not *Helix cuprea* Cox 1868 *ut supra.*

Contrariwise, Benson separated this from *H. sublesta* by the more distant ribs, wider umbilicus, colour and larger size from *H. Iuloidea,* Forbes, of the eastern coast of Australia, by its more distant ribs and want of concavity on the upper side. Diam. major 4, minor 3½, axis 1½ mill.

Thiele, again, overlooking this species, referred specimens to *cuprea* with the size 3.75 mm. by 2 mm., the protoconch finely sculptured spirally, and the adult whorls decussate. The size and the sculpture refer the specimens to this species, rather than to *cuprea*. Benson's description is here offered for reference: "Shell broadly umbilicate, orbiculately depressed, horny, furnished with rather remote oblique costulate radials; spire scarcely a little convex, sutures excavate, apex planate; whorls four and one-half, convex, last rounded, aperture subvertical, roundly lunate, peristome acute, umbilicus perspective." Reeve figured the type specimen the same year, and added to the above description "decussated, beneath the lens, in the interstices with very minute spiral striae" and showed this character in his illustration.

Luinodiscus repens sp. nov.

Plate I., fig. 21.

Another of Mr. Sidney W. Jackson's discoveries at the Bow River and Deep River, this species is the largest yet found of this group, measuring 6 mm. in breadth by 2.5 mm. in height.

The shell is fawn flamed with red.

Apex large, of two whorls, finely spirally lirate, about fifteen lirae counted from above, almost a varix intervening before the adult radial sculpture begins. This, on the first adult whorls, consists of about one hundred regular fine radials, the interstices being finely concentrically striate, almost giving the effect of fine beading to the radials.

The shell is flat-topped, the mouth large, while the umbilicus is narrow and deep, measuring about one fourth of the basal breadth.

Luinodiscus tumidus Odhner 1917.

Plate III., fig. 2.

1917 –*Endodonta* (*Charopa*) *tumida* Odhner, Kungl. Svensk., Vetensk., Handl. Bd. 52, No. 16, p. 72, pl. 3, figs. 72-74, Sept. 19. Noonkanbah, Fitzroy River, North-West Australia.

Odhner's description was somewhat brief, but from a paratype more details can be given.

Shell discoidal, spire concave, umbilicus moderately wide (narrow, half the width of the last whorl, Odhner) mouth open lunate no teeth in aperture outer lip thin columella straight slight callus joining lips but outer lip descending a little so that it does not reach above the level of the last whorl, sutures deep, almost excavate, whorls well rounded. The apical whorls are two, ending in a varix, and are sculptured with faint concentric striae which are overridden by distant radial lirae of the same character as the adult sculpture. This consists of regularly closely spaced ridges, about eighty on the first adult whorl and continuing similarly closely packed to the end of the last whorl. The interstices are very finely, regularly, closely, concentrically striate. The type measured 3.9 mm. in breadth, the height 2 mm., the specimen above described being very slightly smaller.

It is curious that the majority of Western Australian Charopids so far found have the apical whorls concentrically striate, the striae varying in strength, thus while *cupreus* has the striae well marked almost lirae, *sublestus* has the whorls almost smooth, the concentric striations being seen only by a strong lens and then they are obscure. The present species has the apex

somewhat differently sculptured, the concentric striae being overridden by distant radials, the forerunners of the adult sculpture. As the shell is also concave above, a feature not seen in any southern shell, a new subgenus **Corinomala** being introduced with *E. tumida* as type.

Genus **EPINICIUM** gen. nov.

Type **E. restifer** sp. nov.

Plate I., fig. 26.

A very beautiful shell sent by Mr. Glauert from Serpentine attracted by the bold ridges, recalling those of the much smaller Eastern *Egilomen.*

Shell small, subdiscoidal, spire a little elevated, whorls rounded, loosely coiled, sutures deep, last whorl rounded, descending in front, mouth obliquely semicircular, outer lip thin, columella straight, umbilicus wide, cavernous, walls steep.

Coloration deep brown. Apex tip smoothish, finely radially striate, succeeded in the adult by strong distant radial ribs, the interstices closely radially striate, the ribs on the last whorl numbering about thirty-five, the last ten before the aperture being crowded. Breadth 4 mm.; height 2.5 mm.

This genus differs from *Luinodiscus* in its smoothish apex, sculpture and widely umbilicate form, and from *Pernagera* in its depressed shell, different apex, sculpture, and umbilical features.

One specimen, dead, from Peppermint Grove, is larger, flatter, and with more ribs, the umbilicus wider, and may for the present be regarded as a subspecies only, **E. r. firmatum** nov.

Genus **DUPUCHAROPA** Iredale 1937.

1937—*Dupucharopa* Iredale, Austr. Zool., Vol. VIII., p. 332, Mch. 12. Orthotype *Helix millestriata* Smith.

Medium size Charopid shells with depressed spire, narrow deep umbilicus, and sculpture of fine radials with fine spiral striation throughout."

The size separates this from most Charopids but the distinction in sculpture must be characteristic, the spiral striations being continuous over the radials, a very uncommon feature.

Dupucharopa millestriata Smith 1874.

1874—*Helix millestriata* Smith, Zool. Voy. Erebus & Terror, Moll., p. 2, pl. 4, fig. 5. Dupuch's I., West Australia.

1894—*Patula millestriata* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 87, June.

1916—*Endodonta millestriata* Hedley, Journ. Roy. Soc., West Austr., Vol. I., p. 220, (p. 71 in separate).

Smith described the species as follows: "Shell thin, horn-colour perspectively umbilicated, depressedly orbicular, ornamented with very close arcuately-radiating thread-like riblets, which are coarser on the upper than the lower surface, entirely covered with microscopic spiral striations, which are continuous on, and between the riblets, spire nearly flat, only slightly elevated; whorls five, slowly increasing, rather convex, separated by a deepish suture, last not descending in front; the umbilicus occupying one-fourth the width of the base; mouth roundly-lunate; peristome simple, thin, columellar

margin a little dilated above. Greatest diameter 7 mill., smallest 6; height 3. Hab. Dupuch's Is., West Australia (Richardson). This small but prettily sculptured species is chiefly characterised by the fine riblets, and the microscopic spiral striations, which are not, as in some other species, interrupted by the riblets, but are continuous over them. The inferior surface is slightly shining, the upper not so."

Smith, later, added: "This is the largest of the W. Australian *Patulae* at present described. Several bear a very strong family resemblance, but appear to be distinguishable in certain minute details."

FAMILY **MICROCYSTIDAE.**

This family comprises many small flattened conoid shells of thin shell and glassy appearance, whose exact relationship must be determined by anatomical examination. So far only one group, with two species, has been discovered and in shell characters it has shown peculiarities sufficient to differentiate it from all East Australian groups.

Genus **WESTRACYSTIS** Iredale 1933.

1933—*Westracystis* Iredale, Rec. Austr. Mus., Vol. XIX, p. 56, Aug. 2. Orthotype *Lamprocystis lissa* Smith.

Smith described the type species in the genus *Lamprocystis*, observing that it was "well characterised by the peculiar dentiform thickening of the columella and the ridge which arises from it, and passes up the very contracted umbilicus." Hedley transferred it to *Microcystis*, but it was obviously more closely related to *Lamprocystis*.

Westracystis lissus Smith 1894.

1894—*Lamprocystis lissa* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 86, pl. VII., figs. 22-23, June; Queen's Islet, Parry Island (Walker); Burner (error for Barrier) Ranges (Cox), North-West Australia.

The first locality, Queen's Islet, is here selected as the type locality Smith's description reading: "Shell narrowly perforate, orbicular, depressedly conoid above, thin, horny, shining, sculptured with very thin growth striae and microscopic spiral striations; whorls five, little convex, narrowly marginate below the suture, the last whorl slightly descending; spire shortly conoidal, rather obtuse at the apex; aperture obliquely lunate, small; peristome thin, the margins approaching, joined by a thin callus, the columella thickened, forming a peculiar tooth above the perforation; umbilicus very narrow, furnished with an intrusive keel terminating at the columellar tooth. Breadth 8.5; height 5 mm."

Westracystis tentus sp. nov.

Plate III., fig. 14.

A large number of specimens, collected by W. W. Froggatt in the Barrier Range, all show an engraved umbilicus, a feature not recorded by the very accurate Smith in his description of *W. lissa*, though he carefully examined the umbilical features. Yet this is a feature of many members of this family.

The Barrier Range species is smaller, less elevated, the umbilical ridge less notable and the umbilical cavity is filled with a gum-like matter. It measures 7 by 4.25 mm. against 8.5 by 5 mm. The umbilicus is also quite open, and though narrow would not be termed "very contracted."

FAMILY HELICARIONIDAE.

This family is based on Tasmanian and Eastern Australian molluscs, which, though sluglike in form, still retain a thin semi-circular thin shell. Many species are known, extending as far north as Cape York, and extra-limital species north of that place have been included. None is known from North-West Australia, while a single species is included from South-West Australia, although the group is absent from South Australia.

The local form has a shell quite unlike that of the Tasmanian and Victorian species, but apparently has a black animal like that of the latter, as Quoy and Gaimard recorded it under the name *Vitrina nigra*, which they introduced on account of the black colour of the animal.

Genus LUINARION Iredale 1933.

1933—*Luinarion* Iredale, Rec. Austr. Mus., Vol. XIX., p. 38, Aug. 2. Haplotype *Helicarion thomsoni* Ancey = *Vitrina castanea* Pfeiffer.

Luinarion was introduced as a subgenus of *Helicarion*, but it seems to stand further apart, as the shell is so unlike that of other Australian Helicarionids that it has not been recognised up to the present although described eighty years ago.

Shell with the spire a little elevated, smooth, somewhat depressedly globose, mouth large, open, subcircular, outer lip, sinuate, receding basally, base convex, columella arched, a little reflected. Shell fragile.

Luinarion castaneus Pfeiffer 1853.

Plate III., fig. 1.

1832—*Vitrina nigra* Quoy and Gaimard, Voy. de l'Astrol., Zool., Vol. II., p. 136, part only (Western Port, Victoria) and King George's Sound, West Australia.

1853—*Vitrina castanea* Pfeiffer, Mon. Helic. Viv., Vol. III., p. 5, (pref. May) Australia.

1854—*Vitrina castanea* Pfeiffer, Proc. Zool. Soc. (Lond.), 1852, p. 56, Mch. 22, 1854. Australia.

1854—*Vitrina castanea* Pfeiffer, Syst. Conch. Cab. (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XI., p. 24, pl. 6, figs. 1-4. Australia (in my collection).

1862—*Vitrina castanea* Reeve, Conch. Icon., Vol. XIII., pl. VI., sp. 37, May (ex Verreaux in Mus. Cum. "chestnut olive").

1868—*Vitrina castanea* Cox, Mon. Austr. Land Shells p. 84, pl. XIV., fig. 11, May, copied from Reeve (colour all wrong).

1885—*Helicarion castaneus* Tryon, Man. Conch., Ser. II., Vol. I., p. 169, pl. 38, fig. 41, July 3. Bad copy of Pfeiffer's coloration.

1889—*Helicarion thomsoni* Ancey, Le Naturaliste, 1889, p. 19. Geographe Bay, South-West Australia.

1895—*Helicarion thomsoni* Hedley, Proc. Malac. Soc. (Lond.), Vol. I., p. 260.

1916—*Helicarion thomsoni* Hedley Journ. Roy. Soc. West Austr., Vol. I., p. 220 (71 in separate).

Quoy Gaimard wrote "Le port du Roi Georges nous a fourni des individus plus petits, (than the Victorian species), vivant sous les arbres,

loin de l'eau douce." Although Cox recorded this note in the earliest catalogue of our Land Shells by himself in 1864, Smith in 1894 wrote "No species of *Vitrina, Helicarion* . . . . are yet known from this region." This was corrected by Hedley, who pointed out Ancey's description of 1889, but also overlooked Quoy & Gaimard's notice. Apparently everyone has omitted notice of Pfeiffer's *castanea,* which, published in 1853, is undoubtedly the present species.

FAMILY **CHLORITIDAE.**

This family comprises many shells covered with a periostracum bearing hairs but, through lumping, species without such a covering are commonly included. The typical *Chloritis* is a large flattened umbilicate shell with a recurved outer lip, and the apex granulose. It is essentially of northern origin, and species occur throughout East Australia as far south as Victoria and along the north coast. However many species have been referred to this group, whose claims are very doubtful and a redistribution is sorely needed. Gude reviewed the series, and went so far as to group all the Australian species, whatever their form, under *Austrochloritis,* a somewhat peculiar conclusion.

Genus **DAMOCHLORA** Iredale 1938.

1938—*Damochlora* Iredale, Austr. Zool. Vol. IX., p. 97, Nov. 30. Orthotype *Helix millepunctata* Smith.

This generic name was introduced for some North-Western species, which Smith placed under *Helix,* using as a subgenus *Chloritis,* the type species being described as minutely punctate and with the form of *delessertiana,* while *rectilabrum* was subgranulose, clothed with a thin scabrous epidermis and the form unlike. It is probable that these are not at all closely related, and in order to stress this point the subgeneric name **Perochlora** is introduced, the apertural characters of the type, *rectilabrum,* reading quite differently.

Damochlora millepunctata Smith 1894.

1894—*Helix (Chloritis) millepunctata* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 88, pl. VII., fig. 11, June. Baudin Island, North-West Australia.

Smith's description reads: "Shell orbicular, widely umbilicate, thin, horny, subpellucid; whorls five, slowly increasing, everywhere minutely punctate, convex, sutures profoundly impressed, sculptured with thin obliquely arcuate growth-striae, last whorl rounded at the periphery, scarcely descending in front; aperture oblique and broadly lunate, spire very short, rather obtuse to the apex; peristome thin, very little thickened, narrowly expanded and reflected; columellar edge very oblique, a little arcuate, dilated a little above where it joins the whorl. Diam. maj. 16, min. 13 mm.; alt. 8.5 mm. Aperture 6 high, 7 broad. *Hab.*—Baudin Island, N.W. Australia. This species has much the general aspect of *H. delessertiana.* It is, however, flatter, and, of course, quite different in sculpture."

Damochlora cassiniensis Smith 1894.

1894—*Helix (Chloritis) millepunctata* var. *cassiniensis* Smith. Proc. Malac. Soc. (Lond.), Vol. I., p. 88, pl. VII., fig. 12, June. Cassini Island, North-West Australia.

Smith briefly described this: "Shell smaller than the typical form, umbilicus a little narrower, aperture more contracted, peristome a little more

thickened. Diam. maj. 14.5, min. 10.5 mm.; alt. 7 mm. Aperture 5 high, 5 broad. Hab. Cassini Island, N.W. Australia. Although smaller and differing from the type in the points referred to, it seems advisable to consider this form as a variety, rather than as a distinct species."

Damochlora rectilabrum Smith 1894.

1894—*Helix (Chloritis) rectilabrum* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 88, pl. VII., fig. 14, June. Parry Harbour, N.W. Australia.

The description given by Smith reads: "Shell orbicular, depressed, umbilicate, pallid brownish, subgranulate, clothed with a thin scabrous epidermis; spire a little elate, obtuse to the apex; whorls five slowly increasing, convex, sutures profoundly impressed, last whorl rounded at the periphery, very slightly keeled, descending slightly in front; aperture almost horizontal, lunate; peristome thin, narrowly expanded and reflected, margins coming together, the basal edge straightened a little towards the columellar dilation. Diam. maj. 13, min. 11 mm, alt. 6 mm. Aperture 4 high, 5.5 broad. Hab. Parry Harbour, N.W. Australia.

A dead specimen devoid of epidermis does not appear nearly so granular as fresh living examples, although traces of the granulation, especially upon the apical whorls, are discernible."

Genus **KIMBORAGA** Iredale 1933.

1933—*Kimboraga* Iredale, Rec. Aust. Mus., Vol. XIX., p. 50, Aug. 2. Orthotype *Chloritis micromphala* Gude.

Gude named a large series of shells under *Chloritis* many of which appear to be not closely related to the genotype of *Chloritis,* while some, such as the present series, seem to have very little affinity.

Shell globose, thin, elevated spire, mouth large, subcircular, outer lip a little expanded, thin, columella broadly reflected, umbilicus deep, open, apex smooth, shining, with faint growth radials only. No periostracum discernible and sculpture of fine growth radials crossed by fine concentric lines. The apex is large, a little eccentric, a half whorl smooth, another whorl finely striate radially, and three adult whorls only. The related, superficially, forms *Gloreugenia* and *Parglogenia* have the apex small and regularly coiled, and the first whorl and a half are succeeded by five adult whorls.

Kimboraga micromphala Gude 1907.

Plate III., fig. 12.

1907—*Chloritis micromphala* Gude, Proc. Malac. Soc. (Lond.), Vol. VII., p. 231, pl. XXI., fig. 6, April 3. Barrier Range, North-West Australia.

The generic details above given cover the species; the coloration is pale fawnish, and the norm measures 28 mm. in breadth and 18 mm. in height, the aperture being about 11 mm. high and broad, the outer lip descending appreciably in front.

[**Parglogenia forrestiana** Angas 1875.

1875—*Helix forrestiana* Angas, Proc. Zool. Soc. (Lond.), 1875, p. 389, pl. XLV., figs. 3, 3a. North-West Australia.

The locality "North-West Australia," almost certainly refers here to an extra-limital locality, as, from the description, the shell is very close to, if not identical with *pelodes* Pfeiffer = *pseudoprunum* Pilsbry. The last named

was also described from north-western Australia, by which Pilsbry intended Port Darwin, which is politically in the Northern Territory. An earlier name still may be *subgranosa* Le Guillou, and the shell has also been known as *prunum* Férussac, which has been shown to be very different. Misled by the incorrect association, Hedley confused the shell, *Kimboraga micromphala,* and thus included *forrestiana* in his W.A. list.]

Genus **TORRESITRACHIA** Iredale 1933.

1933—*Torresitrachia* Iredale, Rec. Austr. Mus., Vol. XIX., p. 55, Aug. 2. Orthotype *Helix endeavourensis* Brazier.

Shell subdiscoidal, spire a little obtusely elevated, vitreous, whorls rounded, sutures impressed, periphery rounded, mouth subcircular, open, outer lip thin, reflected all round, a little thickened basally, columella almost straight, a little reflected, umbilicus narrow, deep, open, showing coiling and not obscured by columellar reflection. Coloration greenish white, unicolor. Apex smooth, adult sculpture close radial ribbing almost ridges above, base smooth save for growth striae.

This North Queensland style of shell appears to travel along the north coast into North-West Australia.

Torresitrachia bathurstensis Smith 1894.

Plate 3, Fig. 2.

1894—*Helix (Trachia) bathurstensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 93, pl. VII., fig. 20, June. Heywood Island and Bathurst Island, King Sound, N.W. Australia.

A curious complication is seen in the fact that the specific name is taken from one island, and the type shell came from the other; these islands lie at each side of the Sound and the species are probably distinct on each island. Curiously enough the specimen before me, collected by Mr. J. J. Walker, is a paratype, but it has no definite locality.

This specimen is very like the species of *Torresitrachia* but can be separated by the finer, closer, and more regular character of the costulation. The type from Heywood Island measured 15.5 mm. in breadth by the height omitted, while the Bathurst Island shell was 13.5 mm. in breadth, again no height being given. The paratype abovementioned and here figured measures 14.5 mm. in breadth and is 8.5 mm. in height. The ribbing on the base is stronger than on the base of the Queensland shells, but is not as strong as on the upper surface nor is it regular.

Torresitrachia monticola sp. nov.

Plate III., fig. 13.

The species of *Torresitrachia* are found on the islands of Torres Strait and along the north coast of Queensland. The occurrence of similar shells on the islands off the North-West Coast was unexpected, but not so surprising as the recognition of a form among the shells collected by W. W. Froggatt in the Barrier (Napier) Range, many miles inland.

This species is flattened, subdiscoidal, whorls rounded, openly narrowly umbilicate, mouth subcircular, open, lips thin reflected, columella arcuate. The apex is smooth, a subvarix separating this from the adult sculpture which consists of deep well separated very regular costulations, which continue onto the base where however they are less marked. Coloration trans-

lucent and glassy. The umbilicus is narrow, deep, only about one eighth the width of the base yet the previous whorling may be seen therein. The outer lip is reflected all round, though thin, and the columella is little thickened. Breadth 15.5 mm.; height 9.5 mm.

The costulations are a little stronger than in the coastal shell, the spire a little more elevated and the umbilicus a little wider.

Genus **BAUDINELLA** Thiele 1931.

1931—*Baudinella* Thiele, Handbuch syst. Weicht., Vol. I., p. 685. Orthotype, *Helix baudinensis* Smith.

1933—*Gonobaudinia* Iredale, Rec. Austr. Mus., Vol. XIX, p. 55, Aug. 2. Orthotype, *Helix baudinensis* Smith.

Thiele's Handbuch was not available when I introduced *Gonobaudinia*, and Thiele's subordination of his subgenus *Baudinella* to *Angasella* is difficult to understand. Small, stout, widely umbilicate with contracted mouth, it resembles no other Australian shell.

Shell discoidal, spire flattened, whorls few, last descending a little, mouth small, broader than high, outer lip thickened and reflected, with a ditch behind, umbilicus wide and open, nearly half the width of the base. The apex is granulose of about two whorls, the adult sculpture developing without any varix intervening: this consists of stout radial ribs with wide interspaces, the ribs running across the upper surface in a sigmoid manner, then with an even curve into the umbilical cavity where twenty-one may be counted on the last whorl. Along the upper part of the last whorl there is a deep depression which causes the eccentricity in the rib development, and this depression appears in the outer lip as a tooth.

Baudinella baudinensis Smith 1893.

Plate III., fig. 9.

1893—*Helix* (*Gonostoma*) *baudinensis* Smith, The Conchologist, Vol. II., p. 97, fig. in text, Mch. 25. Baudin I., North-West Australia (J. J. Walker).

The generic characters are, at present, sufficient to enable the recognition of this bizarre little shell, which measures 6 mm. in breadth by 3 mm. in height. There is a stout epiphragm in the aperture of the shells collected alive.

Genus **SETOBAUDINIA** Iredale 1933.

1933—*Setobaudinia* Iredale, Rec. Austr. Mus., Vol. XIX., p. 55, Aug. 2. Orthotype *Helix collingii* Smith.

The detailed specific account following shows that this differs from the preceding genus in the essential distinction that the shell is covered with a pilose periostracum. Otherwise it is larger, lacks the characteristic sculpture, and has a more open mouth. It is almost certain that it is not closely related.

Setobaudinia collingii Smith 1893.

1893—*Helix* (*Gonostoma*) *collingii* Smith, The Conchologist, Vol. II., p. 98, fig. in text, Mch. 25. Baudin I., North-West Australia (J. J. Walker).

As no shells are available in this case, Smith's account reads: "Shell flatly discoidal, with the spire only very little raised above the body-whorl, rather openly umbilicated, light brown above, and pale beneath. When in

fresh condition the surface is covered with a thin, shortly pilose epidermis. Worn shells exhibit innumerable minute punctures showing where the short delicate setae have been. Whorls 4½, regularly and rather slowly increasing, moderately convex, and separated by a deep sutural line, besides the punctures, exhibiting fine lines of growth; last whorl rounded at the periphery, only very feebly deflexed close to the aperture, and exhibiting a slight depression above about the middle of the upper margin of the peristome. Aperture somewhat triangular in outline, but with rounded angles, almost horizontal in position; peristome narrowly reflected above, more broadly expanded along the basal margin, especially over the umbilicus. A conspicuous tubercle or prominence occurs on the inner edge of the basal margin, and a less pronounced one within the upper margin corresponding to the slight depression upon the outer surface of the whorl. Breadth 10 mm.; height 4 mm."

Genus **WESTRALTRACHIA** Iredale 1933.

1933—*Westraltrachia* Iredale, Rec. Austr. Mus., Vol. XIX, p. 55, Aug. 2. Orthotype *Trachia froggatti* Ancey.

This generic name was introduced for a number of species, which Ancey had, with great doubt, referred to *Trachia*. The species are flattened helicoids with low spires and keeled or subkeeled periphery, narrow umbilicus and transverse mouth sometimes basally flattened and indistinctly toothed. Although generally smooth and shining, the type is granulose and dull, and it may be that the smooth species should constitute a separate subgenus, which may be called **Zygotrachia** the species, *W. alterna*, being named as type.

Westraltrachia froggatti Ancey 1898.

Plate III., fig. 10.

1898—*Trachia froggatti* Ancey, Proc. Linn. Soc. N.S.W., Vol. XXII., p. 774, pl. XXXVI., fig. 2, June 4. Oscar Range, 100 miles inland from Derby, North-West Australia (W. W. Froggatt).

Shell small, subconical, depressed, stout, spire a little elevated, whorls flattened, sutures little impressed, last whorl acutely keeled, mouth oblique, outer lip expanded and a little recurved. Apex radially finely subgranose, adult sculpture flattened coarse granulation finer on the base.

Westraltrachia derbyi Cox 1892.

Plate III., fig. 6.

1892—*Helix (Hadra) derbyi* Cox, Proc. Linn. Soc. N.S.W., Ser. 2, Vol. VI., p. 566, pl. XX., figs. 4, 5, May 23, Derby District, North-West Australia (W. W. Froggatt).

1894—*Helix (Trachia) derbyana* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 92, pl. VII., fig. 19, June. Burner (error pro Barrier) Ranges, Derby, North-West Australia.

Shell small, subdiscoidal, spire a little elevated, whorls little rounded, sutures impressed, umbilicate, umbilicus narrow, deep, columella reflected, mouth open, outer lip a little reflected with a slight subnodulation on base. Coloration whitish marbled with brown flames above, a post peripheral brown band, rest of base dirty white, shell shining. Apex smooth, adult sculpture faint growth lines only. Breadth 11 mm.; height 6 mm. Collected on the Barrier (= Napier) Range by W. W. Froggatt.

Westraltrachia orthocheila Ancey 1898.

Plate III., fig. 8.

1898—*Trachia orthocheila* Ancey, Proc. Linn. Soc. N.S.W., Vol. XXII., p. 774, pl. XXXVI., fig. 4, June 4. Oscar Range, 100 miles inland from Derby, North-West Australia (W. W. Froggatt).

Shell a little larger than the preceding, subdiscoidal, spire scarcely elevated, whorls scarcely rounded, sutures impressed, umbilicus narrow, deep, columellar reflection small, outer lip thin a little reflected, mouth open with no basal subnodulation nor flattening. Coloration whitish marbled above, with a brown band below the periphery, the rest of the base white, shell shining. Apex smooth, and only fine growth lines seen on the adult whorls. Breadth 13-14 mm., height 6¼-7 mm.

The Oscar Range is twenty miles distant from the south end of the Napier (or Barrier Range), and its shell fauna appears to be different although this species is very close to *derbyi*.

Westraltrachia alterna sp. nov.

Plate III., fig. 17.

Shell large for this genus, subdiscoidal, spire a little elevated, whorls slightly rounded, sutures impressed, last whorl descending a little, subkeeled, mouth flattened horizontally. The apical whorls, two in number, are smooth, the adult four and a half sculptured only with regular striae, which become more distant on the last whorl. Outer lip reflected, base of lip flattened and almost nodulose, columella broad, angularly joining the base of the lip, reflected. Umbilicus narrow, open, half hidden by the reflection of the columella. Coloration horny, banded with dull brown above and below the periphery, base almost white. Breadth 17 mm., height 9 mm. Collected on the Barrier Range (i.e., Napier) by W. W. Froggatt.

Westraltrachia increta sp. nov.

Plate III., fig. 16.

Shell large, not as large as preceding, conical, spire elevated, whorls rounded, last subkeeled a little descending at the aperture, the mouth flattened horizontally. Colour pale brownish white banded above and below the periphery with broad brown bands, the base dirty white. The two apical whorls are smooth, the adult four and a half have only subobsolete striae vanishing on the base. The umbilicus narrow, almost concealed by reflected columella, which is broad and almost angularly meets the base which is flattened and almost subnodulose. Breadth 15.5 mm., height 9.5 mm. Collected by W. W. Froggatt on the Barrier (= Napier) Range.

Genus **QUISTRACHIA** gen. nov.

Type **Trachia monogramma** Ancey.

Shell thin, subdiscoidal, spire a little elevated, whorls rounded, umbilicus narrow, perspective, outer lip thin, a little reflected, subcircular open mouth, columella rather broadly reflected.

Although hitherto classed with the preceding this shell is unlike any of the *Westraltrachia* in texture and form, and is nothing like *Rhagada*.

Quistrachia monogramma Ancey 1898.

Plate III., fig. 20.

1898 *Trachia monogramma* Ancey, Proc. Linn. Soc. N.S.W., Vol. XXII., p. 775, pl. XXXVI., fig. 3, June. Oscar Range, N.W.A. (W. W. Froggatt).

In addition to the characters mentioned above, the shell is horny brown with a darker brown on peripheral band. The apical whorls are smooth as is the rest of the shell save for indistinct growth lines, the whole surface slightly shining ("oleoso," Ancey wrote). The figured shell measures 17 mm. in breadth by 10 mm. in height, while the type, a unicum, measured 15.5 by 8.5 mm.

[**Helix australis** Menke 1843.

1843—*Helix* (*Helicella*) *australis* Menke, Moll. Nov. Holl. Spec., p. 6 (Apl. 11), among limestone rocks at Mount Eliza near the Swan River.

1853—*Helix australis* Pfeiffer, Syst. Conch. Cab. (Martini & Chemnitz), ed. Kuster, Bd. I., Abth 12, pt. 2, p. 276, pl. 123, figs. 7, 8 (after June, 1852). Specimen from Menke Collection figured.

1852—*Helix australis* Reeve, Conch. Icon., Vol. VII., pl. 131, sp. 803, Oct. Swan River, New Holland. Mus. Cuming.

This species has caused a lot of trouble, yet it seems certain that it is merely a South African shell mixed with the Western Australian collection of Dr. L. Preiss. Why this has remained on the list, when this possibility was known is curious. Reeve noted, "A small striped species of European aspect," while of the South African shell he wrote, "Closely allied to a well-known European form." Menke himself compared it with a South African shell, and Benson recorded that "this South African representative could not be refound by Dr. Bacon." Smith questioned the identity of Reeve's specimen with Menke's species, and placed the shell under *Xerophila*, a European subgenus. So it may be omitted from Western Australian lists as it is unlike any local shell in size and form.]

FAMILY **XANTHOMELONTIDAE.**

The most notable mollusc in North Australia is a large thick globose shell, for which many years ago the descriptive name, *Xanthomelon*, was introduced. It is common about Port Darwin, and goes eastward along the coast round the Cape York Peninsula and down towards Moreton Bay. As far as yet is known this form does not occur in Western Australia, an extraordinary result from superficial knowledge. In the interior of Australia, apparently degenerate relations live, and these penetrate into Western Australia in the mid and southern areas. This series, named *Sinumelon*, appears to be characteristic of the Centralian Area; different forms, species or genera being developed on each Range.

Genus **SINUMELON** Iredale 1930.

1930—*Sinumelon* Iredale, Vict. Naturalist, Vol. XLVII., p. 120, Nov. Haplotype *Helix nullarborica* Tate.

1932—*Notobadistes* Cotton and Godfrey, South Austr. Naturalist, Vol. XIII., pp. 169-170, Aug.-September 30. Orthotype *Helix bitaeniata* Cox = *flindersi* Angas.

These desert living Xanthomelontids, ranging all through the interior in suitable places, enter into southern Western Australia, and apparently all the

subgroups appear there. Shells small for the family, subglobose, more or less openly umbilicate, no definite sculpture, longitudinal growth ridges overridden by granulation, mouth subcircular, open, the columella thickened and reflected.

Sinumelon nullarboricum Tate 1879.

Plate III., fig. 19.

1879—*Helix nullarborica* Tate, Trans. Proc. Phil. Soc. Adelaide, South Austr., 1878-9, p. 133, pl. VI., ff. 1 a-b, ex p. 126, *nom nud.* Bunda Plateau, Nullarbor Plain, South Australia.

Shells from Eucla agree in detail with paratypes of Tate's species. These are subglobose, dirty white, sculptured with rough radials, spire a little elevated, umbilicus narrow, columella thickened, outer lip thickened.

The two apical whorls are smooth and shining, but show under a lens very fine radials towards the suture. The rude irregular radials show dents on the last whorl, which appear concentrically as if they were broken rough incised lines, but fine incised concentric lines may be seen on the base of some specimens subordinate to the denting. The columella is reflected, almost concealing umbilicus, which is encircled by a ridge.

Height 14 mm., breadth 16 mm.

Sinumelon datum sp. nov.

Plate III., fig. 18.

1895—*Helix angasiana* Hedley, Proc. Malac. Soc. (Lond.) Vol. I., p. 260, July. Eucla, Western Australia.

Not *Sinumelon godfreyi* Iredale, Rec. Austr. Mus., Vol. XIX, p. 52, Aug. 2, 1933, new name for *Helix angasiana* Pfeiffer, Journ. de Conch., Vol. X., p. 228, pl. X., fig. 2, July 1, 1862: near Lake Torrens, South Australia.

Shell subglobose, broader than *nullarboricum,* with the spire less elevated, the sutures deeper, the umbilicus wider and more open, the columella more curved and reflected, the outer lip reflected but not thickened. Coloration dirty white.

The one and a half apical whorls have more prominent radial sculpture easily seen with a lens, the adult sculpture being rough radials with granulose subordinate sculpture, the grains lengthening on the last whorl into broken radials. The dents are less marked and even more concentrically arranged. Breadth, 19 mm.; height 14 mm. Type from Eucla. Shell from Madura larger and broader but obviously conspecific.

Sinumelon kalgum sp. nov.

Plate III., fig. 25.

From Hannans, Kalgoorlie and Lake Kalgoorlie dead shells (which were probably coloured in life) appear to be relations of the *fodinale* series. They are stouter than *datum,* and have not the deep sutures of that species, and the sculpture differs. The shell is subglobose, stout, spire short, sutures impressed but not subcanaliculate as appear those of *datum.* The apical whorls are not so markedly striate, while the radials are finer and the delicate granulation present never becomes radial, and there appear to be no signs of concentric striae nor any denting. The mouth is more vertical and

more circular, while the umbilicus is more hidden though still open: the columella thickened with the outer lip reflected. Breadth, 20 mm.; height, 17.5 mm.

Bednall's record of *fodinalis* (Trans. Roy. Soc., South Austr., Vol. XVI., p. 63, Dec. 1892), from between Victoria Spring and Fraser Range may refer to this species.

Sinumelon lennum sp. nov.

Plate III., fig. 21.

1892—*Helix (Galaxias) perinflata* Bednall, Trans. Roy. Soc. South Austr., Vol. XVI., p. 62, December. Cavanagh Range. About three miles south of Camp 58, Victoria Desert. Between Fraser Range and Yilgarn Goldfields, Western Australia.

Not *Helix perinflata* Pfeiffer, Proc. Zool. Soc. (Lond.), 1863, p. 528, Apl. 20, 1864, MacDonnell Ranges, Central Australia.

Representatives of the *perinflata* series occur throughout the interior of South-West Australia varying in size and form according to locality.

Shell subglobose, spire short and conical, whorls rounded, sutures impressed, umbilicus very narrow hidden by reflection of columella, mouth large and subcircular. Coloration green. Apex finely granulated, adult whorls 4½, sculptured with faint radial growthlines, with irregular granules covering the whole surface tending to lengthen into beaded radials. Breadth, 24 mm.; height, 21 mm. (type from Boulder).

Specimens from Madura are broader with the same height, the spire being shorter and the body whorl more swollen; these measure 26 mm. in breadth by 21 mm. in height, and may be called **S. l. mutuum** subsp. nov.

Sinumelon vagente sp. nov.

Plate III., fig. 24.

From Mt. Singleton, inland from Geraldton, comes a relation of *perinflata,* more elevated and less inflated than *lennum,* with a stronger granose sculpture.

Shell subglobose, spire short, whorls rounded, sutures impressed, umbilicus very narrow almost concealed by expansion of columella, mouth large, round, outer lip thin. Coloration brownish green. Apex finely radially granulose, adult whorls four, sculptured with fine irregular growth radials which are overridden by a fine granulation.

Columella strongly reflected and united to the outer lip by a thin callus. Breadth, 21 mm.; height, 19 mm.

Genus **PLEUROXIA** Ancey 1887.

1887—*Pleuroxia* Ancey, Conch. Exchange, Vol. II., pt. 3, p. 38, September, new name for

1864—*Angasella* Angas, Proc. Zool. Soc. (Lond.), 1863, p. 521, Apl. 20, 1864, ex A. Adams MS. Haplotype *Helix cyrtopleura* Pfeiffer.

Not *Angasiella* Crosse, Journ. de Conch., Vol. XII., p. 50, footnote, Jan. 1, 1864.

These shells, referred on account of anatomical details, to the family Xanthomelontidae, are very unlike typical members of that family in every conchological feature.

The type has the spire depressed, the shell discoidal, the umbilicus very wide and open, the mouth circular, lip a little reflected; the apex is granosely radiate, the radial sculpture developing into ribs, the grains continuing as a subordinate feature. The south-western species, represented by *oligopleura*, have the apex smooth, spire elevated, shell subdiscoidal, sometimes subglobose, the mouth circular, with the lips continuous, the umbilicus narrow. The sculpture is similar but coarser, and this series is separated as a new subgenus, **Angasietta**.

The Gantheaume Bay species, *P. abstans*, however, has the apex coarsely granular, spire elevated, the umbilicus moderately wide, the mouth circular, lips continuous, expanded rather broadly and constricted behind, and is therefore subgenerically differentiated as **Gantomia** nov.

Pleuroxia polypleura Tate 1899.

Plate III., fig. 27.

1899—*Angasella polypleura* Tate, Trans. Roy. Soc. South Austr., Vol. XXIII., p. 246, pl. VI., figs. 2a-c, Dec. Bunda Plateau, Great Australian Bight, South Australia.

1879—*Helix cyrtopleura* Tate, Trans. Proc. Phil. Soc. Adelaide, South Austr., 1878-9, p. 126, not of Pfeiffer, 1862.

1895—*Helix cyrtopleura* Hedley, Proc. Malac. Soc. (Lond.), Vol. I., p. 260, July, not of Pfeiffer, Journ. de Conch., Vol. X., p. 227, pl. X., fig. 4, July 1, 1862.

Shell subdepressed, flattened, widely umbilicate, with about sixty sigmoid threadlike ribs, the interspaces coarsely granular, the apex large and smooth, breadth 18 mm., height 10.5 mm. Specimens from the road between Madura and Mundrabilla agree in size and sculpture and one is here figured. The umbilicus is better described as narrow and open, not much more than one-fifth the width of the base, while the large open subcircular mouth has the thin lip reflected, and the lips are connected by a strong body callus. Shells collected at Newman Rocks are similar in shape and sculpture but much smaller with the umbilicus a little wider, the granulation finer. The largest measures 13.5 mm. in breadth and 8 mm. in height, and is subspecifically named **Pleuroxia polypleura elfina** nov.

Pleuroxia commenta sp. nov.

Plate III., fig. 26.

Specimens collected by Mr. Charles Barrett, the famed Victorian naturalist and writer, on the Nullarbor Plains were recorded as *P. polypleura*. Better knowledge allows their description as distinct, and the exact locality proves to be Hampton Tablelands, inside the West Australian boundary.

Shell small, subdepressed, spire a little elevated, sutures impressed, whorls rounded, last whorl flattened above and then rounded, a little descending in front, mouth large, subcircular, outer lip a little reflected, umbilicus narrow, deep, open. The coloration of the living shells is a dirty brownish white. Very similar in general appearance and size to *P.p. elfina*, but a little more depressed, and with much coarser sculpture. The ribs are much stronger, more distant, and the granulation almost obsolete, the ribs numbering forty to forty-five. The mouth and umbilical features are very similar to those of the preceding. The shell measures 13 mm. in breadth by 7 mm. in height.

Pleuroxia oligopleura Tate 1894.

Plate III., fig. 28.

1894—*Hadra oligopleura* Tate, Trans. Roy. Soc. South Austr., Vol. XVIII., p. 193, Nov. Eyre's Sand Patch, 160 miles west from Eucla, West Australia (Adcock).

1896—*Angasella oligopleura* Tate, Rep. Horn. Sci. Exped. Centr. Austr., pt. II., Zool., p. 219, pl. XIX., fig. 39, Feb. "Flinders' Range, South Australia," error only, through interchange of localities with *H. wilpenensis* only.

"Similar to *H. crytopleura* (sic) but the plications sharper, higher, and about one-third less in number (35 to 40); the outer lip is thin, and the whorl is more constricted behind it. Diameters, 14.15 and 12; height, 8; height of aperture 6 mm." Topotypes agreed with this diagnosis but shells from 70 Mile Tank east of Balladonia are a little larger and flatter, and probably belong to the same subspecies that occurs on the Hampton Tableland and at Cardanumbi, west of Eyre. This subspecies is altogether larger, more depressed the last whorl flattened above and rounded below, the periphery subkeeled, and the rib sculpture much more pronounced and the ribs only about thirty in number, interstitial granulation obsolete. The coloration of the living shell is brownish white, and the type measures 18 mm. in breadth and 8.5 mm. in height, the subspecies being named **Pleuroxia oligopleura numba** nov.

Pleuroxia gascoynensis Smith 1894.

1894—*Helix (Trachia) gascoynensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 93, pl. VII., fig. 13, June. Gascoyne District, Western Australia (H. P. Woodward).

"Shell depressed, orbicular, broadly and openly umbilicated, whitish, rather solid; whorls four, convex, sutures deeply impressed, closely and minutely granulated, sculptured with oblique rugae or irregular rugose plicae, the two apical smoother, the last whorl rounded or subangulate at the periphery, descending conspicuously in front, the underside rugose; spire flat, apex obtuse, a little elevated; aperture subhorizontal, rounded; peristome continuous, appressed to the last whorl, narrowly expanded, the lower margin broadly dilated. Diam. maj. 12.5, min. 10 mm.; alt. 5.5 mm. Aperture 4 high, 4.5 broad. It is similar in form to *H. cyrtopleura*, Pfr., from South Australia, but differs in size and sculpture. It is smaller, flatter, and has the peristome more decidedly continuous. Rather a powerful lens is necessary to observe the fine granulation which covers the entire surface."

Pleuroxia abstans sp. nov.

Plate III., fig. 22.

A series labelled "On chalk, Murchison House, Gantheaume Bay," consists of dead shells, smaller than the preceding, the largest being only 10 mm. in breadth and barely 5 mm. in height, and having the apex coarsely granulose.

Shell small, subdiscoidal, spire scarcely elevated, sutures deep, whorls a little rounded, last whorl descending in front, umbilicate, umbilicus wide, open, mouth oblique, subcircular, chalky white. Apex half whorl strongly granulated, not differentiated from four adult whorls, the granules massing to form radial ribs. On the last whorl these ribs are well marked closely set ridges,

somewhat irregular in spacing, the interstices somewhat obscurely very finely grained. The ridges continue into the umbilicus which is open and about one-third the diameter of the base. The mouth is subcircular, the outer lip thickened and reflected, an antelabial ditch present; the columella is arched, reflected a little, and connects with the outer lip by a strong callus.

[**Pleuroxia radiata** Hedley 1905.

1905 *Xanthomelon radiatum* Hedley, Trans. Roy. Soc. South Austr., Vol. XXIX., p. 163, pl. XXX., figs. 4, 5, 6, December. Mt. Davies, Tomkinson Range, and Musgrave Ranges, Central Australia.

The Tomkinson Range extends across the border into Western Australia, but Mount Davies is on the South Australian side. The Mann Range is also only a short distance on the wrong side of the West Australian border, and in the same paper, Hedley recorded *Thersites basedowi,* described from the Musgrave Ranges, and now placed in the family Hadridae, and *Xanthomelon asperrimum,* now regarded as *Glyptorhagada,* but with a distinct subgenus *Eximiorhagada,* was described from the Mann Ranges. These records suggest many novelties from the multitude of ranges indicated on the map running south-west from the Tomkinson Range to Mt. Margaret, and thence south to Kalgoorlie.]

FAMILY **RHAGADIDAE.**

The notable Caurine faunula is characterised by many species of mollusca of a solid chalky appearance, many with coloured bands, of normal helicoid aspect, quite unlike those from the rest of Australia.

The typical *Rhagada* is a small solid striped Helicoid with the umbilicus closed by appression of the columella; the umbilicus is narrow and open in the juvenile but rarely open in the adult, sometimes showing a chink but commonly completely closed. The only sculpture is growth lines and the mouth is roundly lunate, a subbasal tubercle present. Many species are larger, some more globose, and some with regular sculpture above but the facies of all resembles each other. This family is utilised tentatively to include some species which are not solid, coming from this Dampierian Sub-Area. It is strange that so far no similar shells have been found in the Northern Territory.

The earliest Rhagadoid shells were collected by Péron and Lesueur, and later the collectors with Stokes secured similar shells. Fifty years ago that fine collector and entomologist W. W. Froggatt collected many specimens in the Barrier and Oscar Ranges. A little later an extraordinary addition to our knowledge was made by another entomologist, J. J. Walker, whose official post was engineer on the surveying vessel Penguin. Apparently parties were landed on various islets between Broome and Darwin, and this industrious collector in his search for insects secured a large number of curious land shells. Owing to the donation of this collection to the British Museum the curator of molluscs (E. A. Smith) examined them and found so much novelty that he prepared a List of the Land Shells of Western Australia, the only monographic attempt made. Twenty years ago Dr. H. Basedow explored the Napier Range and again many land shells were procured. Although the general locality "Napier Range" was the same for Froggatt's and Basedow's collections there was so much discrepancy in the material that it became imperative to investigate their collecting grounds as otherwise recorded.

The localities visited by W. W. Froggatt are given in the Proc. Linn. Soc., N.S.W., Ser. 2, Vol. IV., pt. 2, p. 199, Sept. 20, 1889, as follows:— (1)

Ironstone Ridge, 25 miles South-East of Yeeda Station, Fitzroy River; (2) Mount Marmion; (3) Mount North Creek, Napier Range; (4) Lennard River Gorge, Napier Range; (5) Barrier Range Homestead, Napier Range; and (6) Oscar Range, north-east side.

On the other hand an account of Basedow's Expedition has appeared in the Transactions of the Royal Geographical Society of Australasia, South Australian Branch, Vol. XVIII, pp. 105-295, July 17, 1918. From the route thereon given we find that Dr. Basedow passed through the Barker Gorge in the middle of the Napier Range, then retraced his steps and went along the western side northwards to another gap where he found the limestone caves which he later named Wangalinnya Caves. Thus Basedow's localities are quite distinct from those of Froggatt though the general name Barrier or Napier Range was used by both. All Froggatt's shells were collected in the southern end of the Range and in the Oscar Range which lies some twenty miles to the south-east.

I have continually observed that our land molluscs must be studied in conjunction with geographical, geological and climatic conditions. This instance provides a striking example as the variation seen in the two collections (with the same locality label) was not undersood until the geography of the district was known. In a geological sketch plan which accompanies Basedow's account, the Napier Range is shown as Devonian limestone, the approach from Derby as Permo-Carboniferous, while the Kimberley block to the northward appears as Cambro-Ordovician, a pre-Cambrian sector intervening just north of the Napier Range. A peculiar note is the showing of a small patch of Permo-Carboniferous to the south-east of Wyndham whence come some peculiar snails. With regard to the variation seen in the Napier Range collections other factors, such as climatic, may have interfered as this aspect needs consideration.

Genus **RHAGADA** Albers 1861.

1861—*Rhagada Albers*, Die Heliceen, 2nd ed. (Martens), p. 108, "1860." Orthotype *Helix reinga* Gray = Pfeiffer.

The restricted group of true *Rhagada* comprises small shells, of flattened Helicoid aspect, but chalky, rather shining, spire little elevated, sutures impressed, whorls rounded, mouth subcircular, outer lip thin but a little reflected, inner base showing a slight tubercle, columella curved, appressed generally closing the umbilicus in the adult, a narrow perforation always visible in the juvenile stage. Sculpture of obscure radials only. Coloration white with a few coloured bands.

Rhagada torulus Férussac 1819.

Plate IV., fig. 1.

1819—*Helix torulus* Férussac, Hist. Moll. livr. 6, pl. XXVII., figs. 3, 4, November; Syst. Tabl. Hist. Moll., p. 34, Jan. p. 30, June 1821. New Holland (Péron) = Shark Bay, W.A.

The only locality whence Péron could have secured a shell such as Férussac figured is Shark Bay, and we find that, dealing with the natural history of Bernier Island, with which he associated that of Dorre and Dirk Hartog's Isles, he mentioned "two species of land shells extremely numerous, but all dead, occupied great stretches of the interior of the island. One was a small species of *Helix*."

Smith suggested that *reinga* Gray might be synonymous with this species, writing: It seems to me probable that the *H. torulus* Fér., is identical with this species (*reinga*). It was collected by Péron during one of the early French voyages, but the exact part of Australia, where he obtained it is not stated. Accepting this suggestion Hedley used *torulus*, and I utilised it in the Basic List, but in the more detailed examination necessary for this account I found too many discrepancies, and now record *torulus* as available for a Shark Bay shell, which is not at present in our collection.

Deshayes' description agrees with the figure which shows a subglobose, subperforate shell, smooth, white with one ante-peripheral brown band: the sutures deep, the whorls convex. The illustration is of a shell of the Shark Bay form, being more convex than the more northern *reinga* series.

Rhagada reinga Pfeiffer 1846.

Plate IV., fig. 2.

1846—*Helix reinga* Pfeiffer, Symb. Helic., Vol. III., pp. 31, 50, 73 ex Gray Ms. New Zeal., t. 1, f. 11, 12. New Zealand, type in Pfeiffer Coll., No. 459.

1848—*Helix reinga* Pfeiffer, Mon. Helic. viv., Vol. I., p. 289, cites Chemn., ed. II., Helix, N. 443, t. 73, f. 8-9.

1851—*Helix reinga* Pfeiffer, Syst. Conch. Cab., (Mart. & Chemn.), ed. Kuster, Bd. I., Abth. XIII., Teil 2, p. 52, pl. 73, fig. 8-9.

1852—*Helix reinga* Reeve, Conch. Icon., Vol. VII., pl. 128, sp. 772, Oct.

1890—*Helix reinga* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. VI., p. 185, Dec. 16, refers to Vol. IV., p. 256, pl. 36, fig. 39, Jan. 3, 1889, where the plate was issued but no text appeared with it.

This species was described as "depressedly globose, obliquely striate, whitish, with one chestnut band and many orange lines; spire little elevated, whorls convex; aperture oblique narrow; with a hidden perforation and an obtuse tooth on the base of the mouth, breadth 15, height 10 mm. New Zealand."

The shell had not come from New Zealand, apparently Pfeiffer being misled by inspection of a plate of New Zealand shells which Gray had had prepared. This plate was never issued. A specimen from Broome is here figured as it agrees with the figure and description, and the original specimen may have been collected at Cygnet Bay along with *leptogramma* described about the same time.

Rhagada richardsonii Smith 1874.

Plate IV., fig. 7.

1874—*Helix richardsonii* Smith, Zool. Voy. Erebus & Terror, Moll., p. 2, pl. 4, fig. 14. Dupuch's I., West Australia.

Fig'd Tryon, Man. Conch, Ser. 2, Vol. IV., pl. 36, fig. 35, 36, cf. Pilsbry, id. ib., Vol. VI., p. 185, Dec. 16, 1890.

1877—*Helix elachystoma* Martens, Monatsb. AK. Wissen Berlin, 1877, p. 273, pl. 1, figs. 8-9, May no. Mermaid Strait, North-West Australia (T. Studer).

Fig'd Martens, Nov. Conch., Vol. V., p. 35, pl. 144, fig. 1-4, 1877. Pilsbry, Man. Conch., Ser. 2, Vol. VI., p. 187, pl. XI., figs. 41-43, Dec. 16, 1890.

1894—Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 89, June, (synonymised *H. elachystoma* Martens).

As the localities are adjacent, the descriptions and measurements agree there can be no hesitation in accepting Smith's valuation. The size, 19 mm. in breadth by 12 mm. in height, with the perforation concealed, apparently completely, though this is not certain, the coloration and form will make this species easily recognisable when topotypes are secured.

Rhagada radleyi Preston 1908.

Plate IV., fig. 8.

1908—*Rhagada radleyi* Preston, Proc. Malac. Soc. (Lond.), Vol. VIII., p. 120, text. fig., July 20. Western Australia.

Preston described this, without definite locality, as follows: "Shell discoidal, depressed, white, painted above the periphery with two greyish-brown bands, and below with five bands of the same colour; whorls 4½, transversely marked with lines of growth, the last whorl descending; sutures well impressed; aperture rather oblique, roundly lunate; peristome expanded, scarcely reflexed; columella descending obliquely, expanded over and *almost* concealing the umbilicus and diffused above into a slight parietal callus. Alt. 8.5; diam. maj. 15 mm.; aperture, alt. 6; diam. 4 mm. Allied to *R. reinga*, grey, but smaller, and much more depressed; the umbilicus also is not quite closed, as is invariably the case in that species." It is unfortunate that neither the source nor the collector was given, as from the latter we might have traced the exact locality whence this species came. It was not collected by Froggatt, as it does not coincide with any of his shells.

Rhagada construa sp. nov.

Plate IV., fig. 3.

This was recorded by Ancey as *R. reinga*, but it differs from that species in its larger size, different shape and coloration. Shell globosely depressed, shining, banded, sculptured with faint growth lines only, whorls rounded, sutures depressed, columella thickened, appressed, completely sealing umbilical cavity. Coloration white, variously banded, but always with a well-marked brown peripheral band; sometimes one weaker above and three paler below; in rare cases four above and six below of varying strength, rarely are the minor ones completely absent. The long series available shows variation in size and elevation, the type measuring 16 mm. in breadth and 12 mm. in height; the largest measures 19 mm. by 12 mm., and the least 13 mm. by 9 mm., a flattened form being 16 mm. by 10 mm. The immature shell is subkeeled showing a narrow perspective perforation.

Collected by W. W. Froggatt in the Oscar Range, North-West Australia, "among the limestone."

Rhagada gatta sp. nov.

Plate IV., fig. 5.

This was recorded as *Helix reinga* by Smith, who had only one specimen which he noted was "rather flatter and somewhat more finely sculptured" than specimens from other localities. This is very like *construa*, but is larger, broader, and less conoidal. The bands are just as variable, the

broad medium brown band being omnipresent, but all the others are inconstant, from one to three above, and one to six below of different strength. The columella completely seals the umbilicus in the adult. The type measures 18 mm. in height, and 12.5 mm. in breadth.

This was collected by Dr. H. Basedow about the middle of Napier Range, while W. W. Froggatt had previously collected it towards the south end of the same range.

Rhagada mimika sp. nov.

Plate IV., fig. 4.

This is almost a miniature of *gatta* rather than of *construa,* but constantly shows more banding, having usually two bands above the median broad band, and five below, all being fairly strongly coloured brown. The shell has the umbilicus completely sealed, and the type measures 12.5 mm. in breadth with 9 mm. in height, and was collected by W. W. Froggatt in the Napier Range "on grass, etc." These are always small, and the columellar tooth is more marked than in the larger shells.

Rhagada basedowana sp. nov.

Plate IV., fig. 6.

A large series, collected by Dr. H. Basedow "on trees and on Triodia tussocks" off the Limestone Caves at the north end of the Napier Range, is uniformly chalky white, the characteristic median band being missing. Some of the juveniles are faintly banded but the coloration soon disappears. As some hundreds were collected this is a striking feature, the shells being solid with the umbilicus completely sealed, but the immature deep narrow perforation persists until the shell is practically full grown, these juveniles being notably keeled, and the last whorl is almost subcarinate. The type measures 15 mm. in breadth and 10 mm. in height, the series varying from 13 to 15 mm. in breadth and 9 to 11 mm. in height.

Rhagada sutra sp. nov.

Plate IV., fig. 9.

This differs from the preceding four species in coloration, but notably in that the umbilicus is never completely sealed up. The shell is small, similarly formed to the preceding forms, but the coloration has massed so that the general appearance of the shell is brownish with a few whitish bands. A few adult shells and many immature ones were "found under logs and damp stones" by W. W. Froggatt in the Napier Range. The type measures 12 mm. in breadth by 8 mm. in height.

Rhagada convicta Cox 1870.

Plate IV., figs. 10-13.

1870—*Helix convicta* Cox, Proc. Zool. Soc. (Lond.), 1870, p. 171, pl. XVI., f. 6, Nov. 11. Nichol Bay, West Australia.

Fig'd. Pilsbry, Man. Conch. (Tryon), Ser. 2 (pt. 23), Vol. VI., p. 187, pl. 14, f. 65 (copy of Cox's figure); pl. 35, figs. 8, 9, 10, Dec. 16, 1890.

1877 *Helix convicta* Martens, Monatsb. Ak. Wissen. Berlin, 1877, p. 272, pl. I., figs. 6, 7, May No. Mermaid Straight, North-West Australia (T. Studer).

Fig'd. Pilsbry, Man. Conch. (Tryon), Ser. 2 (pt. 23), Vol. VI., p. 187, pl. 30, figs. 7, 11, Copies of Marten's figs. Dec. 16, 1890.

The type and a series of paratypes are bright shining white with a subsutural and a peripheral narrow band of golden brown of medium elevation, subglobose, spire whorls slightly rounded, sutures lightly impressed, last whorl well rounded, base convex, outer lip thick, reflected, columella short, reflected, sealing the umbilicus. Apex apparently smooth but showing fine radial growth lines, the adult sculpture consisting only of similar growth lines with a very fine concentric lining. The type measures 25 mm. in breadth by 18 mm. in height, and for this solid form of Rhagadoid shell a new subgenus, **Tumegada**, is proposed, *convicta* Cox being the orthotype.

The paratypes show comparatively little variation save in the number of the coloured bands, some having two or three above the periphery and six or seven thin ones below the periphery. Many odd shells from the general locality differ in detail but the reason for the differences cannot be ascertained without exact locality. However, one specimen from the Strelly River, collected by Dr. J. R. Cleland, is smaller with less elevation, measuring 20 mm. in breadth by 14 mm. in height, and may represent a new subspecies **R. c. strella** nov.

A couple from Tambrey Station, Fortescue River, are as large as the preceding but flatter, duller in coloration and measuring 20 mm. in breadth by 13.5 mm. in height and these may be subspecifically named **R. c. tambra** nov.

A series collected on Rosemary I. (so named by Dampier) shows a brownish-white shell with three or four pale brown bands, the specimens are smaller than the typical form but comparatively more elevated, the type measuring 18 mm. in breadth by 14 mm. in height, and is regarded as a subspecies **R. c. perprima** nov.

Rhagada tescorum Benson 1853.

Plate IV., fig. 14.

1853 *Helix tescorum* Benson, Ann. Mag. Nat. Hist., Ser. 2, Vol. XI., p. 30, Jan. 1. Shark's Bay, West Australia.

Fig'd. Reeve, Conch. Icon., Vol. VII., pl. 171, sp. 1154, Oct. 1853. Cox, Mon. Austr. Land Shells, p. 63, pl. IX., fig. 5, May 1868.

1890—*Helix tescorum* Pilsbry Man. Conch. (Tryon), Ser. II., Vol. VI., p. 187, Dec. 16, for Tryon, Vol. IV., p. 256, pl. 36, f. 34, Jan. 3 1889.

1894—*Helix tescorum* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 89, June.

Smith noted: "In form and size this species is very like *H. convicta;* it is, however, remarkable for the caniculate (sic) suture" adding "It is within the range of possibility that this feature is due to weathering. If, in reality, such be the case, this species should undoubtedly be united with *H. convicta.*"

Benson remarked, "the single specimen . . . is apparently in a subfossil state."

Rhagada oscarensis Cox 1892.

Plate IV., figs. 15 16.

1892—*Helix* (*Hadra*) *oscarensis* Cox, Proc. Linn. Soc. N.S.W., Ser. 2, Vol. VI., p. 565, pl. XX., figs. 6-7, May 23. Oscar Ranges, 20 miles from Derby, North-West Australia (W. W. Froggatt).

1894—*Helix* (*Rhagada*) *inconvicta* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 90, pl. VII., f. 10, June. Oscar Ranges, 120 miles S.E. of King Sound, North-West Australia.

Shell rather depressed, spire small, last whorl keeled at the periphery, umbilicus not sealed. Apparently this species is restricted to the Oscar Ranges, but there appears to be local variation as in addition to a series of fifteen "under stones" agreeing with the type, and obviously paratypes and topotypes, there is another series of twenty-five "crawling about on the ground" which consists of uniformly smaller shells. Their elevation varies a little, sometimes even more depressed than the larger species, at others comparatively more elevated. These show more colouring, being generally horn with slightly darker flaming above, a broad brown band below the periphery, which fades basally into almost white. The shell is thinner, the lip a little more expanded, and the umbilicus is a little more open. Measurements, breadth 17-18 mm., height 11-12 mm. These may be called **R.o. perca** subsp. nov., the typical shell measuring 18 mm. in breadth by 11 mm. in height.

Rhagada astuta sp. nov.

Plate IV., fig. 17.

Among the shells collected at Koolan Island, Yampi Sound, was one more flattened, and upon closer examination it was seen to be sculptured on the upper surface.

Shell flattened, subdiscoidal, spire little elevated, whorls rounded, mouth oblique, wide, open, but lips not flaring, the columella reflected almost closing umbilicus, which is, however, still left open; almost a subnodule seen basally on inner edge of lip. The apex worn, but apparently finely striate, striae being seen at suture, the adult whorls sculptured by oblique radials above, the under surface smooth; the radials are very numerous, regular, and distinct. Breadth 20 mm., height 12 mm.

This species is nearest *oscarensis* in form and character, but is even flatter and is easily distinguished by the upper sculpture. This feature is so alien to the true *Rhagada* that this species may prove very distinct, and in order to keep this point in view a new subgeneric name, **Thetagada**, with this as type, is introduced.

Genus **PARRHAGADA** Iredale 1938.

1938—*Parrhagada* Iredale, Austr. Zool. Vol. IX., p. 114, Nov. 30. Orthotype *Thersites woodwardi* Fulton.

This group comprises solid shells with short spire, broad body whorl and the mouth open, the outer lip expanded as a flange giving them a very distinct appearance. The type has the umbilicus tightly sealed, but some of the species, though agreeing very closely in every other feature, leave the umbilicus slightly open.

A very curious ecological note states that one of the most solid was collected "on trees off the Limestone Caves." The solidity of the tree-dweller can only be explained by the abundance of lime in their environment.

Parrhagada woodwardi Fulton 1902.

Plate IV., fig. 18.

1902—*Thersites* (*Rhagada*) *woodwardi* Fulton, Proc. Malac. Soc., (Lond.), Vol. V., p. 33, fig. in text, April. North-West Australia.

This species was described by Fulton from specimens sent him by B. R. Woodward, without definite locality. Two specimens in the Perth Museum

are labelled "types," and these are certainly very distinctive in appearance. having a short spire, the umbilicus sealed, but with the mouth open, the lips expanded in a manner quite unlike that of the species *convicta* and *inconvicta,* with which it has been confounded.

The spire is subconical, a little elevated, the periphery subkeeled in the earlier whorls, the last whorl well rounded, the mouth a little descending, the outer lip expanded all round giving it a flaring appearance; the columella reflected, flattened, entirely closing the umbilicus, which is very narrow and open in the young. The shell is chalky white, somewhat bright, not dead, and there is no sculpture save faint growth lines. The type measured 22 mm. in breadth and 15 mm. in height.

Many shells from "On trees off the Limestone Caves," north end of the Napier Range, collected by Dr. H. Basedow.

Parrhagada sedula sp. nov.

Plate IV., fig. 20.

A single specimen collected by Dr. H. Basedow "in rocks" at Limestone Caves, North end Napier Range, differs in size and coloration from those collected on trees somewhere in the same locality. Shell small, whorls rounded, sutures deep, spire a little elate, coloration brownish cream fading on the last whorl, mouth open, lip thin reflected all round, umbilicus sealed. The sculpture is of the same kind, but appears to be a little coarser than in the larger shells, while the apical whorls are smooth and shining, a minute radial striation being only obscurely seen under a strong lens. Breadth 17 mm.; height 11 mm.

Parrhagada detecta sp. nov.

Plate IV., fig. 22.

A fine series, collected by Dr. Herbert Basedow in the Barker River Gorge, Mid Napier Range, differs from another long series secured by the same collector "on trees off the Limestone Caves" at the northern end of the Napier Range, in their smaller size but more in their shape. The whorls are more flattened, the sutures less impressed, the spire more depressed and rounded, the last whorl showing a little subkeeling, and the mouth not so thrown out, more in line with the spire, the outer lip however flaring as in *woodwardi,* and the umbilicus sealed. The type is a dead shell measuring 20 mm. in breadth by 14 mm. in height.

Parrhagada commoda sp. nov.

Plate IV., fig. 19.

Another lot of shells, collected by Dr. H. Basedow and labelled Barker River Gorge, are all dead, and divisible into two series, obviously collected at two different places in the Gorge. One series consists of large shells all weathered white, varying from 20 to 23 mm. in breadth and from 14 to 16 mm. in height. In form, height, appearance these agree very closely with *woodwardi,* but differ in the fact that the columella instead of being appressed, sealing the umbilicus, runs into the cavity and covers half the umbilical opening but leaves it quite unsealed. So many shells have been collected that this character is of valid specific worth in this case, though often such is not the case, and each instance must be judged separately.

Parrhagada ferrosa sp. nov.

Plate IV., fig. 21.

This name is given to the smaller shells from the same lot as the preceding as they measure 18 mm. in breadth and 11 mm. in height and are all reddish as if dug out of red earth. These generally agree well with the preceding save in size, and the outer lip is still more expanded and thickened.

In my South Australian essay I pointed out that the variation seen in many cases was difficult to determine. In this case the present "species" may prove to be amply distinct living under different conditions, or it may be an ecological variety only. It may even be a horecol, a name selected to designate a time variety, that is, the shells here treated may be true dwarfs, brought about by climatic conditions of some previous season. It may be a geodecol, that is, a shell living under different ground conditions, the vegetation being unsatisfactory for rapid and full growth, but these items can only be solved by local workers studying these animals under natural conditions.

Parrhagada koolanensis sp. nov.

Plate V., fig. 1.

These shells collected on Koolan Island, Yampi Sound, resemble very closely *P. commoda* but with the spire a little more elevated and the mouth not so much thrown out.

Shell subconical, spire elevated, sides rather straight, whorls little rounded, sutures lightly impressed, last whorl subkeeled, mouth descending, open, subcircular, outer lip broadly expanded all round, columella reflected into umbilical cavity not completely closing it, though obscuring it so that only a wide chink is left apparent. Dead shells chalky white, but there are remnants of a thin yellowish periostracum. There is no sculpture save delicate growth striae, the apex smooth. Breadth 22 mm.; height 19 mm.

In this *Parrhagada commoda* complex, this appears to be a real geographical variant in contradistinction to the forms from the Napier Ranges just preceding.

Genus **AMPLIRHAGADA** Iredale 1933.

1933—*Amplirhagada* Iredale, Rec. Austr. Mus., Vol. XIX., p. 52, Aug. 2. Orthotype *Helix sykesi* Smith.

This group, which I introduced as a subgenus only, appears to be of higher value and has a distinct range.

Shell stout, spire elevated, whorls rounded, mouth rather small, columella with basal tooth, umbilicus more or less covered. While the species are apparently Rhagadoid the elevation of the spire separates them and it may be that they are less closely related than would appear at first sight. The complexity of the group necessitates subdivision, as in the past through lack of close examination the confusion reached a stage almost defying simplification.

Amplirhagada sykesi Smith 1894.

Plate V., fig. 3.

1894—*Helix* (*Hadra*) *sykesi* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 92, pl. VII., fig. 8, June. Parry Island, Admiralty Gulf, N.W. Australia.

A paratype is here figured and described. Shell fairly large, conical, spire well elevated, whorls rounded, sutures deeply impressed, last whorl descending, well rounded though earlier a little keeled, mouth oblique, open,

outer lip thickened and reflected, columella very slanting, bearing a small prominent tubercle anteriorly, reflected over and closing the umbilicus save for a minute chink. Coloration shining with a subsutural and a peripheral narrow band of golden brown. Apex very finely striate, adult sculpture of fine regular radial striae, a subordinate fine concentric lining developing later which almost overcomes the radials on the body whorl. There is a strong creamy callus connecting the columella with the outer lip across the body whorl. Breadth 22 mm. height 18 mm.

Amplirhagada montalivetensis Smith 1894.

Plate V., fig. 5.

1894—*Helix* (*Hadra*) *montalivetensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 91, pl. VII., fig. 21, June. Montalivet I., North-West Australia.

Smith described *sykesi* by comparison with *montalivetensis,* so the process may here be reversed, a paratype again being used. Shell much more depressed than the preceding though the coloration is the same, the mouth is more open, the tubercle on the columella is broader and more flattened, the columella more expanded, but the umbilicus is left more open though obscured. The outer lip seems more expanded with an antelabial ditch present, and the base appears flattened around the umbilicus. Breadth 21.5 mm., height 15 mm.

Amplirhagada herbertena sp. nov.

Plate V., fig. 6.

A specimen collected by Dr. H. Basedow in the Buccaneer Archipelago, the exact island not indicated, was regarded by Hedley as representing "*montalivetensis* Smith var," but it is quite distinct.

Shell fairly large for this group, subconical, spire elevated, base flattened appreciably, the last whorl subkeeled, the whorls fine with two apical whorls which are apparently smooth. The whorls are convex with sutures scarcely impressed producing a characteristic appearance. The sculpture is of faint growth radials, but on the last whorl, with a strong lens, a light subordinate fine concentric striation can be discerned. Mouth well open, outer lip thin, a little reflected, basally thickening and producing a flattened tubercle, columella curved, thickened, reflected, half covering the open narrow perspective umbilicus. Base a little convex, then flattened and surrounding the umbilical cavity with a subdued ridge. Breadth 22 mm., height 17 mm.

Amplirhagada imitata Smith 1894.

Plate V., fig. 7.

1894—*Helix* (*Hadra*) *imitata* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 92, pl. VII., fig. 15, June. Baudin, N. Maret, and Condillac Islands and Cape Bougainville, N.W. Australia.

This was distinguished on account of its coarse sculpture above, and this feature immediately separates it. I select Baudin I. as the restricted type locality and figure a specimen from that locality. Shell medium, elevated, whorls rounded, strongly obliquely striate above, the striations becoming lirae almost, disappearing, however, on the base. A little more elevated than *montalivetensis* and a little less than *sykesi,* it shows the apertural and columellar features of the latter almost exactly. There is, however, no coloration seen, and the breadth is 20 mm., with a height of 15 mm.

Specimens from Vansittart Bay, N.W. Australia, collected by Capt. W. Burrows, are more elevated and have finer sculpture above, although this is still strong and well marked. One specimen shows a peripheral and subsutural brown band. Height 16 mm.; breadth 20 mm. This specimen is named **A. burrowsena.** (Plate V., fig. 9.)

Amplirhagada combeana Iredale 1938.

Plate V., fig. 10.

1938—*Amplirhagada combeana* Iredale, Austr. Zool, Vol. IX., p. 113, Nov. 30, new name for.

1894—*Helix* (*Hadra*) *imitata* var. *cassiniensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 92, pl. VII., fig. 16, June. Cassini Islands, North-West Australia.

Not *H. millepunctata* var. *cassiniensis* Smith, op. cit. p. 88.

This is a delightful little species judging from a paratype which is here figured.

Shell smaller than preceding, more solid, comparatively more elevated, mouth more thickened, rather smaller, sculpture coarser and more prominent on base, whorls more rounded, sutures deeper. There is also a golden peripheral narrow band, but no subsutural colour can be seen.

Breadth 15.5 mm.; height 12.5 mm.

Amplirhagada burnerensis Smith 1894.

Plate V., fig. 11.

1894—*Helix* (*Hadra*) *burnerensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 91, pl. VII., fig. 18, June. Burner (error pro Barrier) Ranges, Derby District, N.W. Australia (Cox).

This species appears to fall into *Amplirhagada* though it is outside the range of the other *Amplirhagada*. It is quite unlike its associates geographically and I note that Smith allied it to *sykesi*.

A series of sixty labelled by Froggatt "among the limestones" shows a peculiar coloration, the upper whorls greyish white probably through the dead animal, as some are horn or creamy, the last two whorls creamy suffused below the suture and towards the umbilicus with rich amber. The apex is radially granulose, the usual fine growth radial sculpture with a very fine concentric lining present, on the adult whorls. These are rounded, last whorl large, mouth a little descending, outer lip thin, slightly reflected columella straight, short, reflected sealing the umbilicus. Breadth 21.5, height 15 mm.

A smaller horny shell, associated with the preceding, is more conical, thinner, last whorl subkeeled, mouth more open, apex less granulose, adult sculpture a little coarser. Its exact status is at present unknown, it may be a horecol, but for the present it is named **A. terma** sp. nov. the type measuring 15.5 mm. in breadth by 11.5 mm. in height. (Plate V., fig. 8.)

Amplirhagada novelta sp. nov.

Plate V., fig. 12.

Shell subglobose, spire conical, rather elevated, whorls rounded, last whorl large, descending at mouth which is large, open, subcircular, outer lip thin, slightly expanded, columella small but reflected, sealing the umbilicus.

The dead shell is whitish with a faint brownish peripheral narrow band. The apex is almost smooth, but shows slight radial striae, the adult sculpture is faint radial growth lines, somewhat irregular in strength. Breadth 23 mm.; height 17.5 mm.

Compared with *sykesi,* this species has a much more conical spire, more flattened whorls and lacks the columellar tubercle while the umbilicus is completely sealed, there is not the slightest chink showing.

Collected on the Drysdale River, Napier Broome Bay, North-West Australia.

Genus **TENUIGADA** gen. nov.

Type **T. percita** sp. nov.

Many thin shells are labelled "In rocks, Limestone Caves, Napier Range," and these do not correlate with any of the named groups. Shell thin, helicoid, a little conical, umbilicate, whorls rounded, sutures shallow, last whorl rather bulky, mouth descending, a little oblique, subcircular, the outer lip thin, reflected, the columella slanting, broadly reflected across and hiding the umbilicus but not appressed.

These shells have a different texture from the preceding Rhagadoid forms while the columella does not enter the umbilical cavity nor is it appressed but expands across the umbilical opening. The apex is finely radially striate, whereas generally in Rhagadoid shells the apical whorls are smooth.

Tenuigada percita sp. nov.

Plate V., fig. 14.

Shell thin, transparent, subglobose, spire somewhat elate, conical, whorls rounded, sutures little impressed, last whorl with a faint peripheral keel at beginning, periphery well rounded finally, outer lip a little descending, mouth roundish, open, outer lip thin, reflected all round, the columella broadly angulately reflected over umbilicus which however is not closed by it. The apex is rather coarsely radiate, the radials breaking up into granules, the succeeding sculpture being rather coarse growth radials, almost radial riblets, which become weaker with age when concentric striation appears, and this can also be seen obscurely on the base. A callus connects the outer lip and the columella. Coloration pale brownish horn. Breadth 19 mm.; height 14 mm.

Collected in rocks at the Limestone Caves, North End of Napier Range, by Dr. H. Basedow.

Tenuigada ignara sp. nov.

Plate V., fig. 13.

Collected with the preceding, but probably in a slightly different location, were many smaller specimens of the same type, but there were paler in coloration, more depressed, the peripheral keel more noticeable, smaller, the mouth more descending, the umbilicus comparatively larger and more open. The apex is more strongly granulose, the adult radial sculpture weaker, the concentric striae scarcely discernible. Breadth 16 mm.; height 10.5 mm.

Genus **EXILIGADA** gen. nov.

Type **Exiligada negriensis** sp. nov.

Mr. Richard Helms, in the year 1896, collected a number of shells at Negri Outstation, twenty-five miles north of Ord River Station, East Kimberley. Two species were procured and they do not fall into any Rhagadoid

group previously known, and are quite unlike any other type of Australian land mollusc.

The shell is depressed, spire little elevated, whorls a little rounded, last whorl rounded, base somewhat flattened, umbilicate, mouth fairly large, outer lip a little recurved.

The notable features are the texture and coloration. The shell is strong, but not as stout as true *Rhagada*, and the shells are banded profusely but not in the *Rhagadoid* style. In the type the bands are broken into bars by growth periods, but in the second species the bands are continuous, twelve to sixteen bands being counted on the last whorl. The columella is reflected, leaving the umbilicus exposed in the type but almost concealing it in the second species.

Exiligada negriensis sp. nov.

Plate V., fig. 4.

Shell subdiscoidal, large, spire a little elevated, whorls little rounded, last whorl however well rounded at the periphery, mouth descending a little, aperture oblique, subcircular, open, outer lip reflected a little all round, flattened basally, columella slanting, broadly reflected but not obscuring the umbilicus, which is narrow but open, shell rather solid.

Coloration peculiar: whitish encircled by a number of brown lines interrupted by growth stages so that the lines appear as a series of dashes, the lines are practically of the same width and number about a dozen on the last whorl, three above the peripheral one which is no stronger than the others, the remainder on the base. The apex is quite smooth, and apparently stopped by a varix, the adult whorls being only sculptured by very faint growth striae only. The base is somewhat flattened, the umbilical area excavate.

Breadth 22 mm.; height 11 mm.

Exiligada qualis sp. nov.

Plate V., fig. 2.

Shell with the spire more elevated than in the preceding species, the whorls a little rounded, the sutures impressed, the mouth large, the outer lip a little recurved but not flattened basally. The shell has the same texture as the preceding and is surely related, but at first sight it differs as the coloured bands are unbroken. The ground colour is whitish and the lines are more numerous, two about the periphery being much broader than the remainder and a brighter red-brown. There are half a dozen above and half a dozen below with even one narrow line between the two broad ones.

The apex is apparently smooth but there are microscopic radial striations present, the adult shell being very finely radially growth striate throughout.

The columella is a little arcuate and expanded, closing the umbilicus save for a chink.

Breadth 20 mm.; height 14 mm.

Genus **PLECTORHAGADA** Iredale 1933.

1933—*Plectorhagada* Iredale, Rec. Austr. Mus., Vol. XIX., p. 52, Aug. 2. Orthotype *Helix plectilis* Benson.

This group has a different facies from *Rhagada,* the spire being more conical, the mouth descending more rapidly and being more circular, the umbilicus being open though hidden by the expansion of the columella, and

the characteristic sculpture. The apex is smooth, the adult whorls rugosely plicate, the plicae irregular, and overall a curious granulation. This sculpture is so peculiar that the type species appears to have been described three times, Reeve calling the sculpture "crumpled," which is probably the best word used.

Plectorhagada plectilis Benson 1853.

Plate V., fig. 15.

1853—*Helix plectilis* Benson, Ann. Mag. Nat. Hist., Ser. 2, Vol. XI., p. 29, Jan. 1. Shark Bay, West Australia.

Fig'd. Reeve, Conch. Icon., Vol. VII., pl. 172, sp. 1162, Oct., 1853.

Cox, Mon. Austr. Land Shells, p. 44, pl. IX., fig. 17 (copy of Reeve's figure); pl. XX., fig. 8, from a painting of the type by Angas, May, 1868. Tryon, Man. Conch., Ser. II., Vol. III., p. 215, pl. 49, fig. 18, 1887. Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. VI., p. 88, pl. 35, figs. 16, 17, 18, 1890.

1854—*Helix paleata* Reeve, Conch. Icon., Vol. VII., pl. 199, sp. 1399, Dec. Banks of the Swan River, Australia (Bacon).

Tryon, Man. Conch., Ser. II., Vol. III., p. 215, pl. 49, fig. 17, 1887. (Cox and Pilsbry, opp citt., treat this as a synonym of above.)

1864—*Helix carcharias* Pfeiffer, Proc. Zool. Soc. (Lond.), 1863, p. 528, Apl. 20, 1864. Shark Bay, West Australia.

Fig'd. Cox, Mon. Austr. Land Shells, p. 45, pl. XX., fig. 12 (from a painting of the type by Angas), May, 1868.

The locality "Banks of the Swan River" is definitely incorrect, the species being only known from Shark Bay. Some are labelled Dirk Hartog's Island and it is possible that there may be races or even distinct species on the islands such as Dirk Hartog, Bernier, Dorre, as well as Peron Peninsula. Péron recorded that helicoid land-shells were abundant on those islands, and we have no series for examination yet. The specimen labelled "Dirk Hartog's Island" is undoubtedly the same as those labelled "Shark Bay," and probably all are from the one lot. This measures 15.5 mm. in breadth by 11 mm. in height, and agrees very closely with Angas' painting of the type of *plectilis*. Pfeiffer's *carcharias*, according to Angas' painting, is more conoidal, and is a living specimen, "flesh-coloured," all the dead shells being white.

Rensch (Zool. Jahrbuch (Syst.), Jena, Bd. 63, heft 1, pp. 1-130, Apl. 12, 1932), dealing with the Molluscan Fauna of the Sunda Expedition, has recorded (p. 94), *Rhagada plectilis supracostulata* Schepman, from Sumba, recording as additional races of *R. plectilis*, *plicata* Preston, *colona* Martens, and *savaensis* Schepman. Such reviews by continental workers, being based on scant material and no local knowledge, are very misleading. The Australian shells, thus associated by Rensch as "races," *plectilis* and *plicata*, have little close relationship, and are very definitely not conspecific. The mere fact that they come from Western Australia seems to be the decisive factor in Rensch's judgment.

Plectorhagada rovina sp. nov.

Plate V., fig. 17.

A very beautiful little shell from Shark Bay, regarded as the missing *H. australis* Menke, is here described, as it is quite unlike the description of the Menkean species. Shell small, stout, subglobose with elevated spire, sutures deep, whorls very rounded, mouth large and circular, umbilicus

narrow, open, columellar reflection slight, outer lip thin not reflected, coloration shining white, with two faint brown bands on last whorl, one peripheral, the other midway between this and suture. Apical whorls, one and a half, smooth, adult whorls five and one half, sculptured with close wavy irregular rough ridges, subgranulose, base a little smoother. Columella a little curved with a strong glaze connecting inner and outer lip, but not forming a continuous aperture.

Height, 11 mm.; breadth, 12 mm.; aperture, 6 mm. high by 6 mm. broad.

While the rough sculpture is not identical with that of *plectilis,* it recalls that, and no other Western Australian shell has any sculpture at all like. This species is therefore placed tentatively under *Plectorhagada,* but as its shape is so different from that of the type, a new subgeneric name is here introduced, **Idamera,** with *P. rovina* as type.

Genus **BELLRHAGADA** Iredale 1938.

1938—*Bellrhagada* Iredale, Austr. Zool., Vol. IX., p. 114, Nov. 30. Orthotype *Rhagada plicata* Preston.

Smallest Rhagadoid shells, flattened globose, imperforate, sutures almost canaliculate, mouth subcircular, lip little expanded, sculpture of regular radials weaker on the base, the apical whorls large and smooth.

This little shell is quite similar to the type of *Rhagada* but is plicate above, and is here differentiated, as it appears to have an extra-Australian representative in *supracostulata,* which has the umbilicus not completely sealed.

Bellrhagada plicata Preston 1914.

Plate V., fig. 16.

1914—*Rhagada plicata* Preston, Proc. Malac. Soc. (Lond.), Vol. XI., p 13, fig. in text, Mch. 30. Montebello Is., West Australia.

The smallest of the Rhagadoid series, this shell is flattened globose, spire short, very little elevated, whorls little rounded, sutures deep, last whorl descending a little, mouth subcircular, open, outer lip a little reflected, basally thickened; columella slanting, appressed, sealing the umbilicus save for a minute chink, coloration white with one broad peripheral band, two narrower above, and half a dozen below: these are pale brown but may be darker in life.

The sculpture is peculiar, the apical whorls smooth, the adult whorls with flattened oblique distinct radials, these persisting obscurely on the base. Breadth 10 mm.; height 8 mm.

[**Helix dringi** Pfeiffer 1846.

1846—*Helix dringi* Pfeiffer, Symb. Helic., Vol. III., p. 73, "Austral. oriental. (Dring in Mus. Cuming)."

1848—*Helix dringi* Pfeiffer, Mon. Helic. viv., Vol. I., p. 289, "Australia oriental, prope 'Torres Strait' (Dring)."

1852—*Helix dringi* Reeve, Conch. Icon., Vol. VII., pl. 128, sp. 769, October.

1868—*Helix dringi* Cox, Mon. Austr. Land Shells, p. 64, pl. XI., fig. 9, May.

1890—*Helix dringi* Pilsbry, Man. Conch. (Tryon), Ser. II., Vol. VI., p. 186, Dec. 16, fig. for Vol. IV., pl. 36, fig. 40, Jan. 3, 1889, where there is no text.

All these references refer to the single specimen collected by Dring, and credited to Eastern Australia, near Torres Strait. The figure recalls species

of *Torresitrachia,* but these are always openly umbilicated, while this is described as having a covered umbilicus, which suggests Rhagadoid affinity. Dring collected on the West Coast so that it is possible that this species was found somewhere on the west, rather than on the East Coast.]

Genus **GLOBORHAGADA** Iredale 1933.

1933—*Globorhagada* Iredale, Rec. Austr. Mus., Vol. XIX, p. 52, Aug. 2. Orthotype *Helix* (*Hadra*) *prudhoensis* Smith.

I distinguished this form as a subgenus of *Rhagada,* observing that the type species was globose, with open circular mouth, the columella thickened, much reflected and appressed, but not closing the umbilicus, a thick glaze joining the inner and outer lips.

The globose form separates this group clearly and the apertural characters appear distinct from those of true *Rhagada.* The columella crosses the umbilical cavity whereas the *Rhagada* species have it entering it.

Globorhagada prudhoensis Smith 1894.

Plate V., fig. 19.

1894—*Helix* (*Hadra*) *prudhoensis* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 91, pl. VII., fig. 9. Prudhoe Island, N.W. Australia (Lieut. J. W. Combe, H.M.S. "Penguin").

"Shell umbilicate, globose (whitish, clothed with a yellowish epidermis); whorls five convex, rapidly increasing, striate with oblique growth lines, the last whorl large, inflated, obliquely descending suddenly at the aperture; spire obtusely conoidal; aperture rotundately-lunate, length about three-fifths of the height of the shell; peristome interiorly slightly thickened, outwardly scarcely expanded, a little effuse anteriorly, a thin callus joining the margins, columella oblique, reflected, dilated above, almost hiding the umbilicus. Diam. mag. 25, min. 20 mm.; alt. 22 mm. Aperture 14 long, 11.5 broad. Hab. as above.

This is a smooth globular species, probably without much coloration, judging from the only two specimens at hand. These are in a dead condition, without any trace of colour, and probably are more or less bleached. The umbilicus is deep and moderately broad; the inner edge of the oblique columella is gently arcuate, but the outer margin is almost straight or faintly incurved."

Globorhagada leptogramma Pfeiffer 1846.

Plate V., fig. 18.

1846—*Helix leptogramma* Pfeiffer, Proc. Zool. Soc. (Lond.), 1845, p. 127, Feb. 1846. Cygnet Bay, North Australia (Ince).

Fig'd. Reeve, Conch. Icon., Vol. VII., pl. LXXXII., sp. 437, Mch. 1852. Cox, Mon. Austr. Land Shells, p. 41, pl. XI., fig. 4, May 1868. Smith, Zool. Erebus & Terror, Moll., p. 2, pl. IV., fig. 18, 1874. Tryon Man. Conch., Ser. 2, Vol. IV., p. 256, pl. 36, fig. 33, 1887.

Specimens from Broome agree fairly save that they are slightly larger, and topotypical examples are not available.

Shell globose, spire very short, last whorl very large and bulky, whorls rounded, sutures deep, last whorl descending a little, mouth almost circular wide open, outer lip a little reflected all round, columella very slanting across

the umbilical cavity concealing the umbilicus but not closing it, a thick glaze crosses the body whorl from columella to outer lip. Dead shell white with four brownish bands on body whorl, two narrow above the periphery, one a little broader peripheral and another similar just below. Sculpture of growth striae only.

Height 19 mm.; breadth 21 mm.

Globorhagada montebelloensis Preston 1914.

Plate V., fig. 20.

1914—*Rhagada montebelloensis* Preston, Proc. Malac. Soc. (Lond.), Vol. XI., p. 13, fig. in text, Mch. 30. Montebello Is., West Australia.

Shell subglobose, spire short, whorls well rounded, mouth round wide, columella thick reflected, almost closing umbilicus. This is a flatter shell than *leptogramma*, more depressed, somewhat recalling some forms of *Rhagada* but with the columellar features of *Globorhagada*.

Shell brownish white with one peripheral pale brown band. Apex finely radially striate, adult sculpture only of rough radial growth striae, smoother on base.

Height 13 mm.; breadth 17 mm.

Globorhagada obliquirugosa Smith 1894.

Plate V., fig. 21.

1894—*Helix* (*Hadra*) *obliquirugosa* Smith, Proc. Malac. Soc. (Lond.), Vol. I., p. 90, pl. VII., fig. 17, June. Parry Harbour, North-West Australia.

The original description reads: "Shell globose, narrowly perforate, white, clothed with a thin yellowish epidermis, striate with oblique growth lines, everywhere obliquely irregularly corrugated; whorls five convex, rapidly increasing, sutures deeply impressed, last whorl large, globose, slightly descending at the aperture; aperture oblique, broadly lunate, white; spire moderately elevated, somewhat obtuse at the apex; peristome slightly thickened, scarcely expanded above, a little reflected below, the columellar margin dilated broadly, especially at the insertion, thus partly concealing the umbilicus. Diameter major 21, min. 16.5 mm; height 18 mm. Aperture 14 long, 10 broad. Only dead specimens of this species were obtained, almost entirely denuded of the periostracum. The remains of it, however, within the aperture show that it was of a yellowish tint. One example, fresher than the rest, has the spire of a very pale brownish tint, so it is likely that this species, when living, is of a light brownish colour above, and covered with a thin periostracum."

FAMILY **OCCIRHENEIDAE.**

For the present it is better to use a name such as the above to include a species from Western Australia whose status is unknown. I introduced the generic name *Occirhenea* for *Helix georgiana* Quoy and Gaimard, which had been placed previously under *Rhytida*, *Flammulina* and *Zonites*, none of which occurs in this area.

Genus **OCCIRHENEA** Iredale 1933.

1933 *Occirhenea* Iredale, Rec. Austr. Mus., Vol. XIX., p. 48, Aug. 2. Orthotype *Helix georgiana* Quoy and Gaimard.

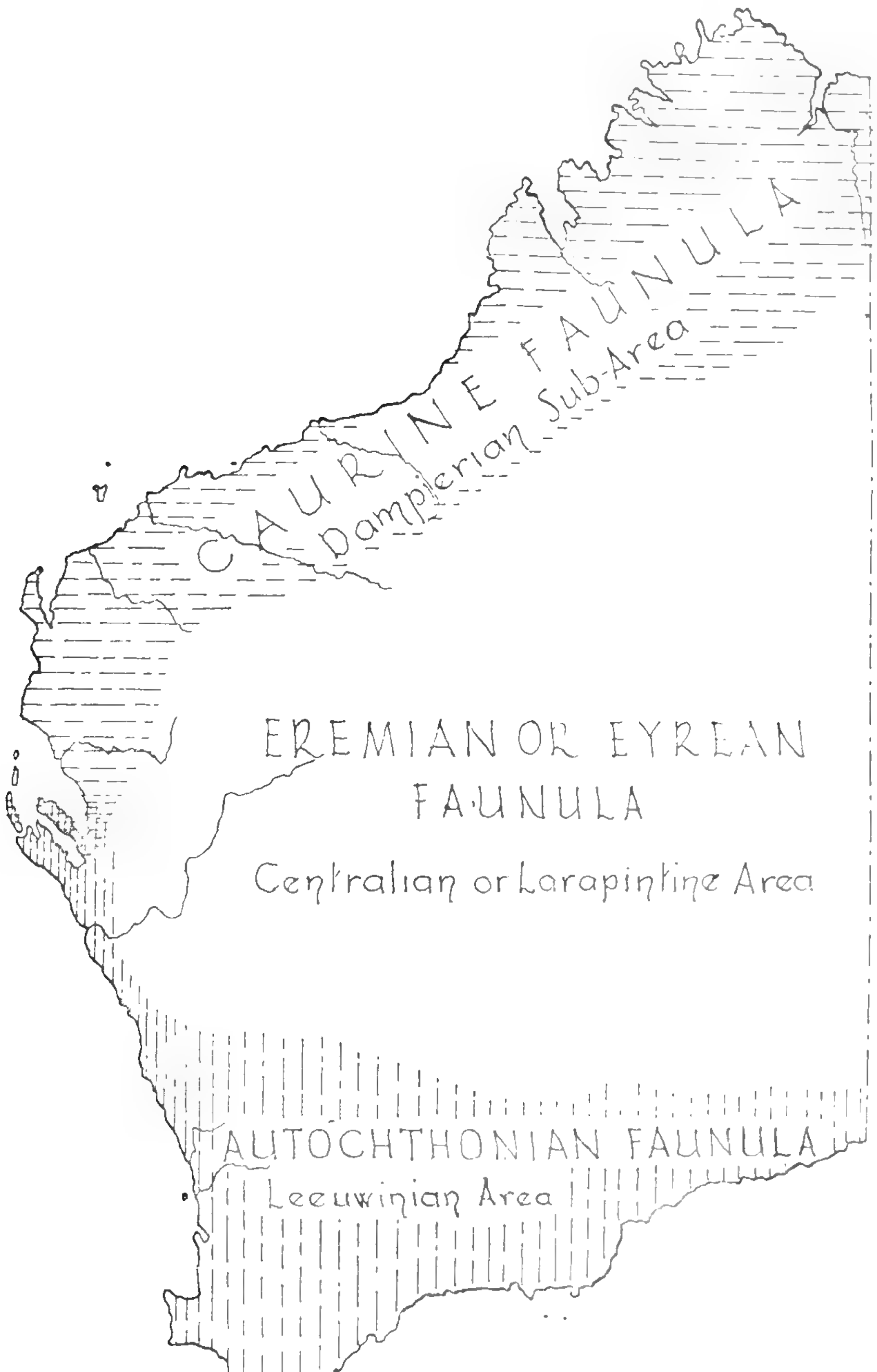
I wrote, "The strongly sculptured base, narrow umbilicus, and produced outer lip differentiate" this species which had previously been placed under *Rhytida*, *Flammulina* and *Zonites*, three genera representing distinct groups of superfamily distinction. Apparently although the figure shows a strongly sculptured base this is an error in the drawing.

Occirhenea georgiana Quoy and Gaimard 1832.

Plate V., figs. 22 and 22a.

1832—*Helix georgiana* Quoy and Gaimard, Voy. Astrol. Zool., Vol. II., p. 129, pl. X., figs. 26-30. King George Sound, South-West Australia.

Shell orbicular, translucid and fragile, strongly striated above, yellow; whorls four, the last cylindraceous; aperture large, subrotund; lip thin. Diameter 5 lines, height 2 lines.



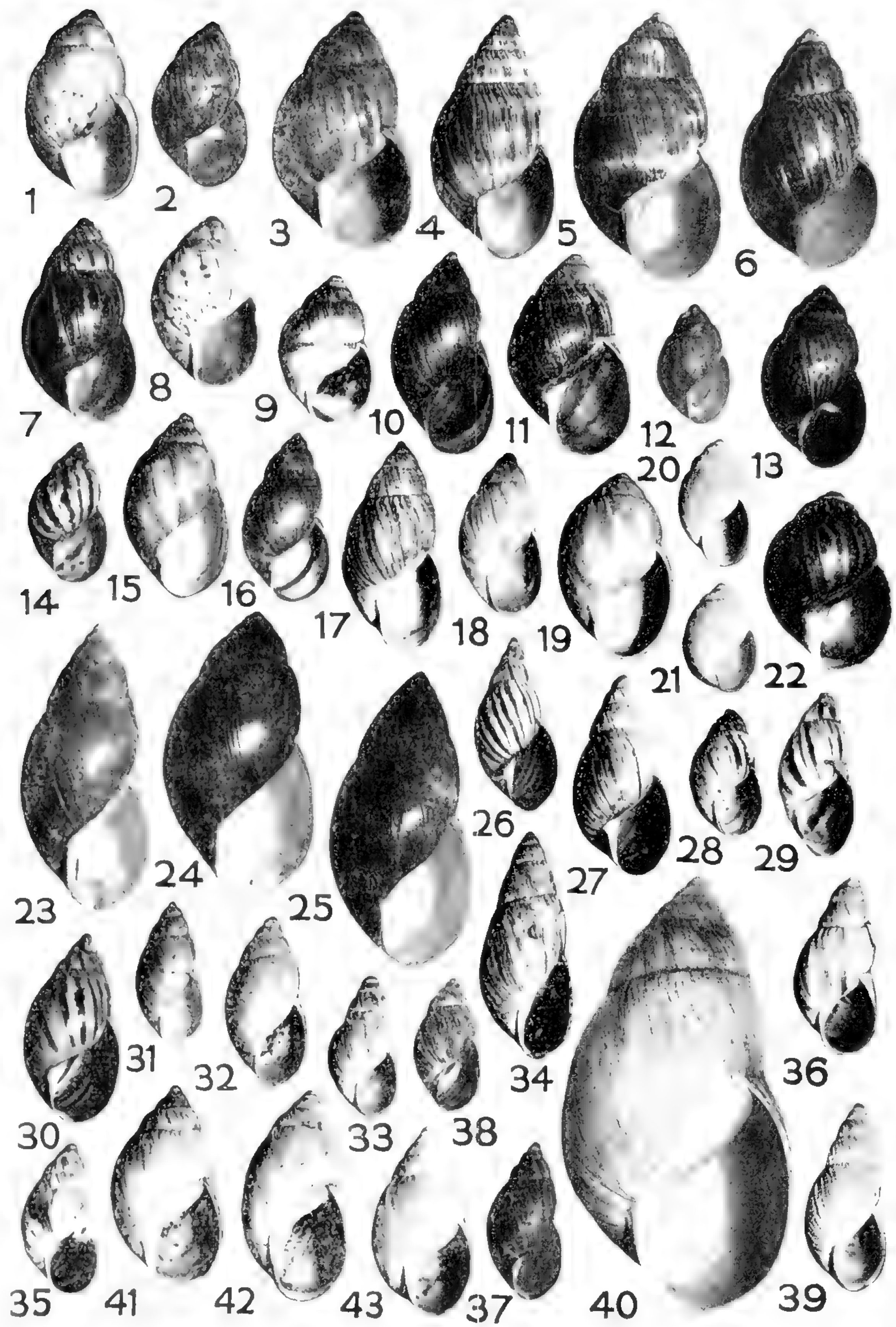
WESTERN AUSTRALIA.

EXPLANATION OF PLATE I.

Fig. 1. *Pleuropoma walkeri* Smith.
2. *Australbinula helmsiana* Iredale.
3. *Themapupa beltiana assorta* Iredale.
4. *Australbinula mooreana* Smith.
5, 5a. *Themapupa lepidula* A. Adams and Angas.
6. *Themapupa beltiana contexta* Iredale.
7. *Australbinula complexa* Iredale.
8. *Themapupa disrupta* Iredale.
9. *Themapupa anapacifica* Iredale.
10. *Omegapilla occidentalis* Iredale.
11. *Austrosuccinea scalarina* Pfeiffer.
12. *Austrosuccinea contenta* Iredale.
13. *Austrosuccinea contenta isolata* Iredale.
14. *Arborcinea menkeana* Pfeiffer.
15. *Austrosuccinea aridicola* Iredale.
16. *Austrosuccinea caurina* Iredale.
17. *Austrosuccinea coxi* Finlay.
18, 28. *Westralaoma expecta* Iredale.
19. *Westralaoma sedula* Iredale.
20. *Gratilaoma cara* Iredale.
21. *Luinodiscus repens* Iredale.
22. *Insullaoma predicta* Iredale.
23. *Pernagera albanensis* Cox.
24, 27. *Annoselix dolosa* Iredale.
25. *Luinodiscus cyaneus* Benson.
26. *Epiiricium restifer* Iredale.

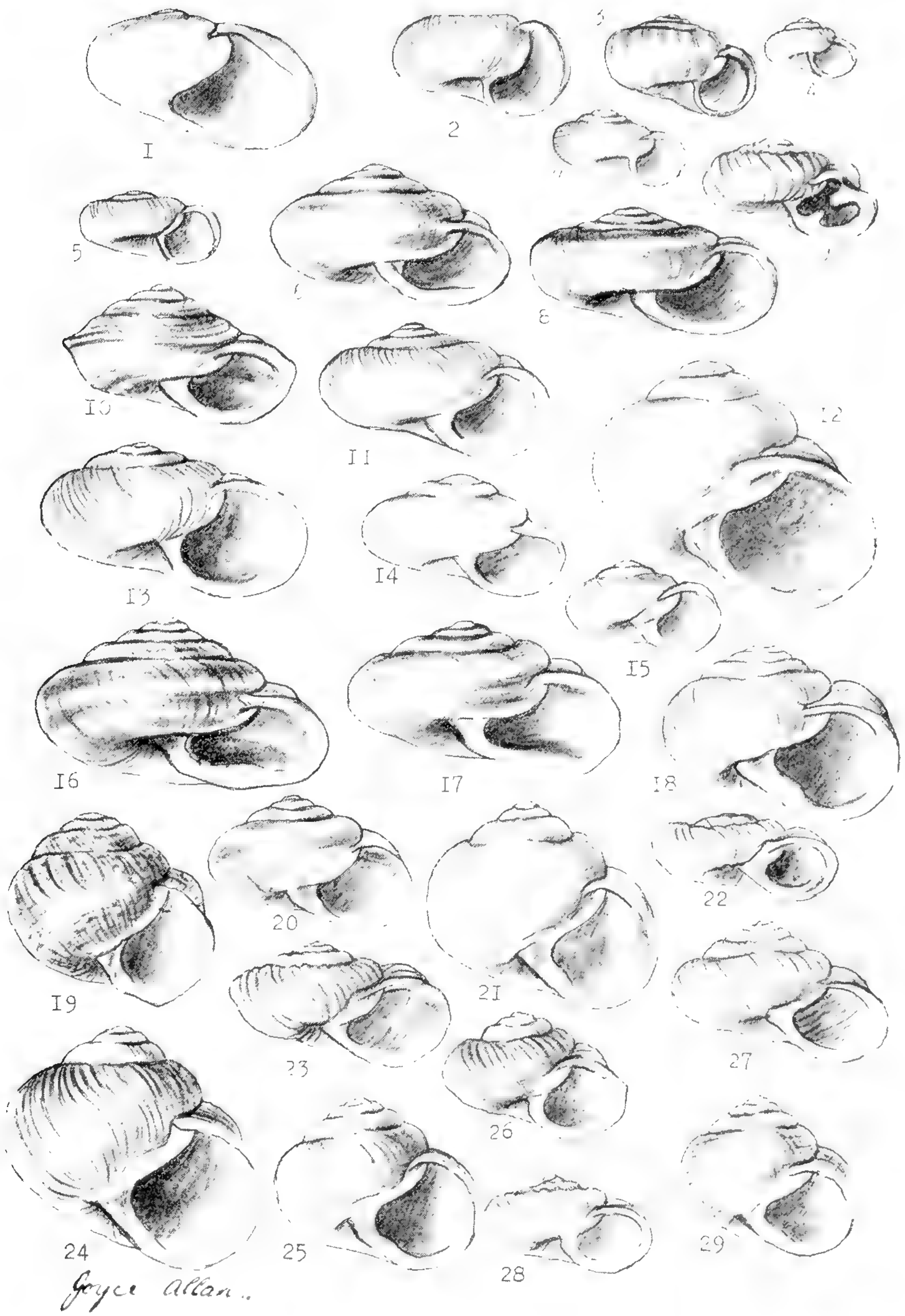
EXPLANATION OF PLATE II.

1. *Bothriembryon melo* Quoy and Gaimard.
2. .. *castaneus* Pilsbry.
3. .. *rhodostomus* Gray.
4. .. .. *hullianus* Iredale.
5. .. .. *grantianus* Iredale.
6. .. .. *wrightianus* Iredale
7. .. .. *perspectus* Iredale.
8. .. *esperantia* Iredale.
9. .. *balteolus* Iredale.
10. .. *serpentinus* Iredale.
11. .. *praecelsus* Iredale.
12. .. *sedgwicki* Iredale.
13. .. *bulla* Menke.
14. .. *bradshawi* Iredale.
15. .. *[illegible]* Iredale.
16. .. *richeanus* Iredale.
17. .. *leeuwinensis* Smith.
18. .. .. *eventus* Iredale.
19. .. *costulatus* Lamarck.
20. .. *minor* Pilsbry.
21. .. *whitleyi* Iredale.
22. .. *perobesus* Iredale.
23. .. *indutus* Menke.
24. .. *glauerti* Iredale.
25. .. *tranki* Iredale.
26. .. *kingii* Gray.
27. .. .. *trilineatus*).
28. .. .. *humilis*).
29. .. *notatus* Iredale.
30. .. *jacksoni* Iredale.
31. .. *maxwelli* Kobelt.
32. .. *perditus* Iredale.
33. .. *sayi* Pfeiffer.
34. .. .. *solidus*).
35. .. *naturalistarum* Kobelt.
36. .. .. large form).
37. .. *revectus* Iredale.
38. .. *brazieri* Angas.
39. .. *gratwicki* Cox.
40. .. *dux* Pfeiffer.
41. .. *barretti* Iredale.
42. .. .. *indictus* Iredale.
43. „ *distinctus* Iredale.



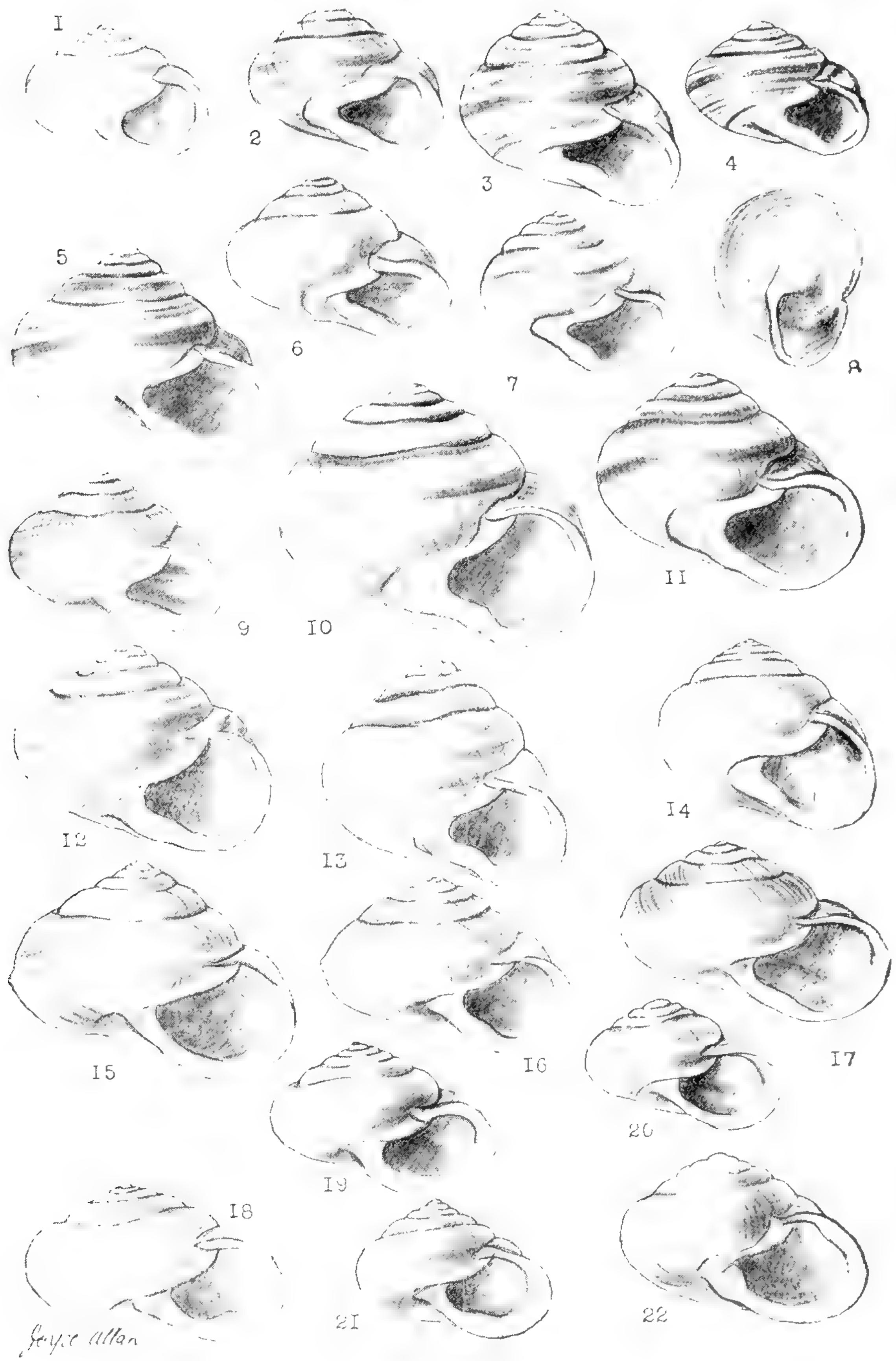
EXPLANATION OF PLATE III.

Fig. 1. *Luinarion castaneus* Pfeiffer.
„ 2. *Luinodiscus tumidus* Odhner.
„ 3. *Pernagera lena* Iredale.
„ 4. *Westralaoma expicta* Iredale.
„ 5. *Luinodiscus cupreus* Cox.
„ 6. *Westraltrachia derbyi* Cox.
„ 7. *Westralaoma aprica* Iredale.
„ 8. *Westraltrachia orthocheila* Ancey.
„ 9. *Baudinella baudinensis* Smith.
„ 10. *Westraltrachia froggatti* Ancey.
„ 11. *Torresitrachia bathurstensis* Smith.
„ 12. *Kimboraga micromphala* Gude.
„ 13. *Torresitrachia monticola* Iredale.
„ 14. *Westracystis tentus* Iredale.
„ 15. *Pleuroxia polypleura elfina* Iredale.
„ 16. *Westraltrachia increta* Iredale.
„ 17. *Westraltrachia alterna* Iredale.
„ 18. *Sinumelon datum* Iredale.
„ 19. *Sinumelon nullarboricum* Tate.
„ 20. *Quistrachia monogramma* Ancey.
„ 21. *Sinumelon lennum* Iredale.
„ 22. *Pleuroxia abstans* Iredale.
„ 23. *Pleuroxia oligopleura numba* Iredale.
„ 24. *Sinumelon vagente* Iredale.
„ 25. *Sinumelon kalgum* Iredale.
„ 26. *Pleuroxia commenta* Iredale.
„ 27. *Pleuroxia polypleura* Tate.
„ 28. *Pleuroxia oligopleura* Tate.
„ 29. *Sinumelon lennum mutuum* Iredale.



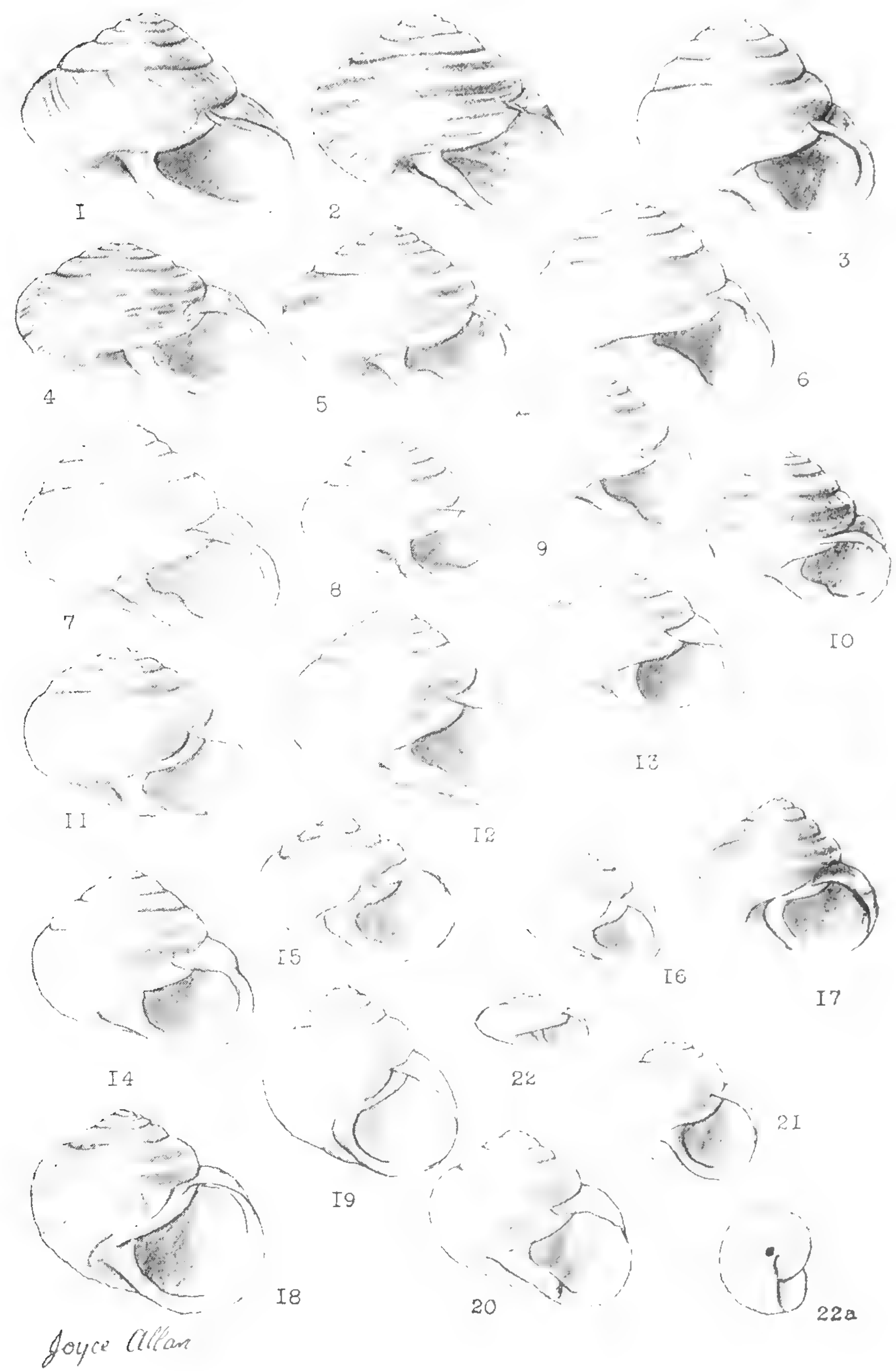
EXPLANATION OF PLATE IV.

Fig. 1. *Rhagada torulus* Ferussac.
,, 2. ,, *reinga* Gray.
,, 3. ,, *construa* Iredale.
,, 4. ,, *mimika* Iredale.
,, 5. ,, *gatta* Iredale.
,, 6. ,, *basedowana* Iredale.
,, 7. ,, *richardsonii* Smith.
,, 8. ,, *radleyi* Preston.
,, 9. ,, *sutra* Iredale.
,, 10. ,, *convicta* Cox.
,, 11. ,, ,, *strella* Iredale.
,, 12. ,, ,, *tambra* Iredale.
,, 13. ,, ,, *perprima* Iredale.
,, 14. ,, *tescorum* Benson.
,, 15. ,, *oscarensis* Cox.
,, 16. ,, ,, *perca* Iredale.
,, 17. ,, *astuta* Iredale.
,, 18. *Parrhagada woodwardi* Fulton.
,, 19. ,, *commoda* Iredale.
,, 20. ,, *sedula* Iredale.
,, 21. ,, *ferrosa* Iredale.
,, 22. ,, *detecta* Iredale.



EXPLANATION OF PLATE V.

Fig. 1. *Parrhagada koolanensis* Iredale.
„ 2. *Exiligada qualis* Iredale.
„ 3. *Amplirhagada sykesi* Smith.
„ 4. *Exiligada negriensis* Iredale.
„ 5. *Amplirhagada montalivetensis* Smith.
„ 6. „ *hebertena* Iredale.
„ 7. „ *imitata* Smith.
„ 8. „ *lerma* Iredale.
„ 9. „ *burrowsena* Iredale.
„ 10. „ *combeana* Iredale.
„ 11. „ *burnerensis* Smith.
„ 12. „ *novelta* Iredale.
„ 13. *Tenuigada ignara* Iredale.
„ 14. „ *percita* Iredale.
„ 15. *Plectorhagada plectilis* Benson.
„ 16. *Bellrhagada plicata* Preston.
„ 17. *Plectorhagada rovina* Iredale.
„ 18. *Globorhagada leptogramma* Pfeiffer.
„ 19. „ *prudhoensis* Smith.
„ 20. „ *montebelloensis* Preston.
„ 21. „ *obliquirugosa* Smith.
„ 22. & 22a. *Occirhenea georgiana* Quoy & Gaimard.



INDEX.

INDEX—*continued.*

2.—SIMPSONITE (sp. nov.) FROM TABBA TABBA, WESTERN AUSTRALIA.

By H. BOWLEY, F.A.C.I.

Read: 9th August, 1938; Published 26th June, 1939.

During October 1934 a few specimens of a creamy crystalline detrital mineral ranging in specific gravity from 5.92 to 6.05 were received at the Government Laboratory with the information that they came from Mining Lease 312 being worked for manganotantalite at Tabba Tabba in the North-West Division.

The freshly fractured surfaces showed that they consisted of a transparent colourless mineral intergrown with a creamy white translucent material. The crushed powder is almost pure white. A preliminary chemical examination of one crystal by D. G. Murray showed the presence of much tantalic oxide with a large amount of aluminium, an appreciable quantity of lime with some sodium and fluorine and traces only of iron and manganese. This was sufficient to indicate that it was a mineral not previously recorded so it was decided to give it the name Simpsonite in honour of Dr. E. S. Simpson who has held the position of Government Mineralogist in this State since 1897 and who, during that period, has made many outstanding contributions to our knowledge of Western Australian minerals, particularly the study of tantalum-bearing minerals.

In 1935 we were indebted to Mr. A. L. Kennedy for a further small parcel (8 lbs. in weight) of similar material from the same locality. As all the specimens appeared to be much weathered and intergrown with an alteration product, the publication of a description of them was held over in the hope that further work on the original matrix of the mineral, a tantaliferous pegmatite vein, would reveal some of the unaltered primary mineral; unfortunately, however, all the specimens received to date are of the same type, so it was decided to present the data available during Dr. Simpson's occupancy of the Presidential Chair of this Society.

Simpsonite occurs as flat tabular crystals in a quartz biotite pegmatite between a quartz blow and a felspar pegmatite outcropping a little to the north of the tantalite workings on Mining Lease 312 at Tabba Tabba (Lat. 20° 43′ S. Long. 118° 57′ E.).

At the time of the writer's visit to the locality in July 1936 the vein had been opened out to a maximum depth of 8 feet.

All the specimens examined showed evidence of crystal development, many of them being similar in appearance, with a pronounced tabular habit, and a somewhat hexagonal outline (see Fig. 1). In no case was a complete crystal obtained, at the most the crystals being only half developed. They ranged in size from 0.5 cm. to 2.4 cm. maximum dimensions.

Parallel crystal growths, and penetration twins are common. Although the characteristic form of the crystals is well preserved all attempts at exact measurements of the interfacial angles on a two-circle goniometer failed owing to the impossibility of obtaining a satisfactory signal, partly due to the matte surface caused by weathering and partly to the development of many vicinal faces and small penetration twins.

Rough goniometrical measurements on crystals obtained by cementing small pieces of thin cover glass to the various faces were:—

Crystal A. ϕ	Crystal A. ρ	Crystal B. ϕ	Crystal B. ρ
0°	90° 9′	0°	97° 7′
9° 28′	91° 7′	56° 52′	90° 40′
57° 0′	86° 1′	57° 53′	87° 4′
55° 56′	91° 6′	54° 25′	90° 5′

The basal plane is strongly developed and from the above readings it is obvious that there is a strong pyramidal development.

The X-ray examination of the mineral will be dealt with in a forthcoming paper by Miss L. E. R. Taylor.*

Under the microscope with reflected light it appears as colourless masses intergrown with a pale cream alteration product. With transmitted light a section of a crystal showed irregular cores of a transparent colourless anisotropic mineral bounded by interlacing veinlets of a small amount of a colourless isotropic mineral, which is intergrown with a pale cream almost opaque granular mineral without any crystal habit whatever (fig. 2). Narrow veins of muscovite and quartz cut across the crystals in places.

The refractive index of the anisotropic constituent, which is that to which I have given the name Simpsonite, was determined by immersion in a mixture of piperine and iodides and is proved to be 2.06 ± with an extreme birefringence in the vicinity of 0.1. The mineral is uniaxial, positive.

No evidence of any cleavage or parting was apparent.

Simpsonite and its associated alteration products are unattacked by HCl and H_2SO_4 but are readily attacked by fusion with caustic alkalies, alkaline carbonates and potassium bisulphate.

Complete analyses were made of two selected crystals with the following results:—

Specimen.	A. Per cent.	A. Mols.	B. Per cent.	B. Mols.
Ta_2O_5	72·31	1637	71·48	1618
Nb_2O_5	·33	12	·32	12
SnO_2	2·00	133	1·19	79
FeO	·16	22	·44	61
MnO	·08	11	·04	6
CaO	3·40	606	3·19	569
Fe_2O_3	·14	9	·48	30
Al_2O_3	16·75	1643	18·64	1829
K_2O	·24	25	·42	45
Na_2O	1·16	187	·68	110
PbO	·42	19	*Nil*	...
F	*·21	111	·38	200
H_2O+	1·35	750	1·39	771
H_2O-	·20	...	·03	...
SiO_2	1·78	296	2·34	390
	100·53		101·02	
$O = F_2$	·09		·16	
	100·44		100·86	
Sp. Gr.	6·525		6·27	
Analyst	D. G. Murray.		J. N. A. Grace.	

*This figure is probably low as determinations of F by an improved method on other specimens have invariably given higher results.

*See page 93 this Journal, Editor.

D. G. Murray proved the absence of TiO_2, BeO, UO_3, ZrO_2 and Rare Earths in Specimen A.

In addition partial analyses were made of several crystals, the results obtained being—

Specimen.	C.		D.		E.	
	%	Mols.	%	Mols.	%	Mols.
3A (mainly Al_2O_3)	15·50	...	16·00	...	18·14	...
CaO	4·48	799	4·46	795	4·12	735
Na_2O	1·09	176	1·13	182	1·02	164
F	·86	453	·89	468	·81	426

The fluorine figures shown in the above partial analyses were obtained by H. P. Rowledge by an improved method.

All the specimens examined showed intergrowths of quartz and mica which would in all probability account for the SiO_2 and K_2O found.

An endeavour has been made to calculate from the analytical figures the constitution of the original Simpsonite and its alteration product.

After deducting the alumina, silica and water necessary to satisfy the potash to form muscovite and the remainder of the silica as quartz we are left with essentially tantalic and niobic oxides, lime, sodium, fluorine and water present as two distinct minerals.

It is to be noted that the partial analysis of specimens C, D and E show a constant molecular ratio of almost 2 : 1 : 1 for the Ca, Na and F respectively, irrespective of the amount of alumina present. This would suggest that these three constituents are combined in that ratio to form one of the tantalum-bearing minerals.

This formula was not adopted for the alteration product for the reason that no known fluotantalate of lime and sodium in that ratio has been recorded whereas the formula for microlite has been established both by analysis and synthesis as $CaNaTa_2O_6F$.

The alteration of tantalites into microlite by replacement of the iron and manganese by lime, sodium and fluorine has been recorded in this State in such cases as the alteration of manganotantalite and tapiolite whilst the alteration of stibiotantalite into microlite has been noted at Varutrask in Sweden.

Deducting the constituents to form microlite, calculated on the basis of the total sodium present, and allowing for the muscovite and quartz present we have the following molecular proportions for the original mineral Simpsonite.

Analysis.	A.	B.
$(Ta·Nb)_2O_5$	4	4
Al_2O_3	5	5
CaO	0·9	1·2
H_2O+	1·8	1·9

giving a formula for the unaltered Simpsonite of

$$2H_2O.CaO.5Al_2O_3.4Ta_2O_5$$

SUMMARY.

Simpsonite is a hexagonal basic tantalate of aluminium and lime with the composition $2H_2O.CaO.5Al_2O_3.4Ta_2O_5$, recorded for the first time from Tabba Tabba, Western Australia.

All the specimens examined were considerably altered.

It was found impossible to separate sufficient quantity of the pure minerals in order to definitely establish their composition.

The formula given for Simpsonite is based on the assumption that the associated alteration product in the specimens examined is microlite, the only known fluotantalate of lime and sodium.

In every case the specimens were too weathered on the surfaces to permit of exact goniometrical crystal measurements.

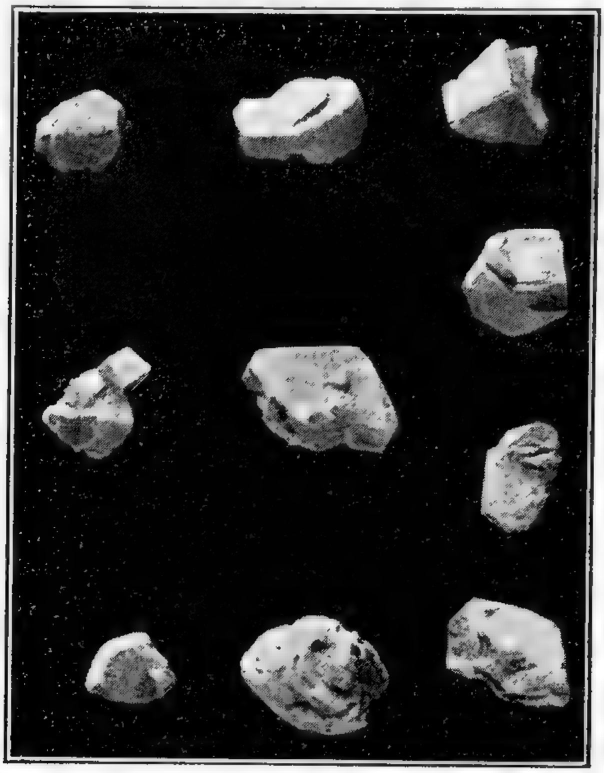


Fig. 1.—Natural size.
(Photo.: B. L. Southern.)

Fig. 2.—O.L. x 35.
(Photo.: J. N. A. Grace.)

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

3.—X-RAY STUDIES OF SIMPSONITE.

By

L. E. R. Taylor, B.Sc. (Hons.).

Read, 9th August, 1938; Published, 26th June, 1939.

With three figures.

Simpsonite is a sodium-calcium-aluminium tantalate which occurs naturally in such poor crystal form that a determination of its crystalline symmetry cannot be carried out macroscopically. It forms natural crystals which appear to conform approximately to the shape of a short hexagonal prism but in no cases have crystals been found which show more than two good basal faces and four vertical faces. When this number of vertical faces does occur, the fourth is generally only a fragment. It is more usual to find one or two basal, and two vertical faces. Various optical methods were devised for the determination of the angle between the faces but the unevenness of the faces and their exceedingly low optical reflecting power rendered measurements inexact. The mineral is very hard and totally resists cleavage.

X-ray methods were adopted for the determination of the crystalline symmetry and crystallographic form. Preliminary measurements were obtained of spacings parallel to the natural faces of the crystal.

Simpsonite and its alteration product meta-simpsonite occur together in the same crystal, the former being recognised by its more transparent nature. If the two species occurred together in the thin sections used in the investigation, the crystalline form must have been similar, as photographs of different parts of the section yielded similar symmetry. The chemical constitution of both simpsonite and meta-simpsonite have been investigated by Mr. H. Bowley.

The most profitable method of X-ray analysis would have been that involving the use of a small single crystal of the mineral, of a size suitable for rotation photographs. An attempt was therefore made to obtain a small fragment of the mineral containing two recognisable natural faces—a basal and a vertical. This was successfully carried out but the first attempts to obtain Laue photographs of it oriented in a known direction proved unsuccessful. It was, therefore, decided that an easier line of approach lay in the investigation of thin sections of the mineral ground from basal and vertical faces, taken from the same specimen and with their relation to one another carefully noted. This method did not enable one to determine the angles between the faces as the former method would have done.

A crystal was chosen which showed three fairly good prism faces and two basal faces. From this crystal a section parallel to one of the basal faces and three sections parallel to each of the vertical faces were obtained in the following manner.

The faces of the crystal were ground to render them smooth and to remove surface material. It was then divided in halves by a cut parallel to the basal faces. The cutting was done with a hack saw, the teeth of which were filled with emery. Two cuts parallel to the first and third vertical

prism faces divided one of these halves into three sections each containing a prism face. Each of these four pieces of crystal were ground parallel to its contained natural face, *i.e.,* four sections were obtained, one parallel to the basal face and one parallel to each of three abjacent prism faces. The order of the vertical sections and their relation to the basal section were carefully noted. The three vertical sections will be designated as *a, b* and *c.* The thickness of the specimens varied from 0.24 to 0.34 mm. Even with a thinness of this order the Laue exposures were long, owing to the presence of the highly absorbing element, tantalum, which formed about 58% of the crystal's composition. The basal section and section *b* contained quite good transparent material. Section *c* consisted of very poor opaque material while section *a* was only fair.

A Hilger-Müller Improved X-ray goniometer spectrograph was used in the course of this work. For the Laue photographs radiation from a Coolidge XP-1 water-cooled X-ray tube was used. A Hilger all-steel gas X-ray tube with a copper target supplied monochromatic radiation as required. The high tension was supplied from a Victor Induction coil with mercury make-and-break. In all exposures the films were backed with a sheet of Levy-West Fluorazure Intensifying screen. With this screen and with 5 m.a. tube current and about 80 K.V.P., satisfactory intensity was obtained with Laue photographs in two hours.

A Laue photograph was taken with the X-ray beam normal to a section and the section adjusted until the symmetry that appeared was made exact. The section was then turned through 90° and reflections of Cu K radiations from the crystal face were obtained by the Bragg method. From the last pictures it was hoped to obtain the spacings of atomic planes parallel to the natural crystal faces.

The basal section was investigated first and proved to give all that was essential to the determination of the X-ray point group of the mineral. The vertical sections verified the conclusions drawn from this section.

Laue photographs of the basal section gave what is undoubtedly a hexagonal symmetry. The symmetry of the photograph is such that six rotations of 60° each about an axis normal to the plane of the film bring similar spots into coincidence. No lines of symmetry exist in the film, *i.e.,* no planes of symmetry exist in the crystal normal to the plane of the basal section and no twofold axes parallel to the basal section. A centre of symmetry in the film is present. The character of the spots varies. They are simple along a line in the film and composite along a line perpendicular to the first. This may be attributed to twinning.

From the point of view of X-rays, the hexagonal system contains only four distinguishable point groups—two in the rhombo-hedral division (3Di and 3Ci*) and two in the hexagonal division (6Di and 6Ci*). The symmetry elements of these four point groups with the resulting symmetry of the Laue photographs taken with the X-ray beam parallel to a threefold or sixfold axis is given in Table 1.

The Laue photograph obtained belongs to the point group 6Ci.

Laue photographs taken with the vertical section normal to the X-ray beam, *i.e.,* with the sixfold axis normal to beam, reveal a line of symmetry across the film. This confirms the conclusions deduced from the pictures of the basal section. Only photographs of vertical section *a* and *b* are shown

* Notation due to Wyckoff.

(Figs. 2 and 3). Section *c* which consisted of poor opaque material gave only very faint reflections but the few reflections obtained conformed with the pattern of the previous vertical sections.

TABLE I.

HEXAGONAL SYSTEM.

Division.	Point Group.	Symmetry Elements.	Resulting Symmetry in Laue Diagrams.
1. Rhombohedral	3Ci (Rhombohedral*)	Threefold axis. A centre of symmetry	Threefold rotational symmetry. No lines of symmetry.
	3Di (Ditrigonal scalenohedral*)	Threefold axis. Three co-planar twofold axes at right angles to threefold axis. Three planes intersecting along threefold axis. A centre of symmetry	Threefold rotational symmetry. Three lines of symmetry.
2. Hexagonal ...	6Ci (Hexagonal bipyramidal*)	Sixfold axis. Plane at right angles to sixfold axis	Sixfold rotational symmetry. No lines of symmetry.
	6Di (Dihexagonal bipyramidal*)	Sixfold axis. Six co-planar twofold axes at right angles to sixfold axis. Plane coincident with plane of twofold axes. Six planes each containing one twofold axis and the sixfold axis. A centre of symmetry	Sixfold rotational symmetry. Six lines of symmetry.

* Nomenclature due to Groth.

This was the limit to which the symmetry of the crystal could be determined by Laue diagrams. The classification is as follows:—the crystal belongs to the hexagonal division of the hexagonal system. It lies in the X-ray point group 6Ci which has the following symmetry elements: a sixfold axis, a plane of symmetry at right angles to that axis, and a centre of symmetry. This X-ray point group contains the crystallographic point groups 6c, 6C and 6Ci. The form of each of these groups and the symmetry elements defining them are given below.

6c—Trigonal bi-pyramidal*; a threefold axis and a plane of symmetry perpendicular to the axis.

6C—Hexagonal pyramidal*; a sixfold axis.

6Ci—Hexagonal bipyramidal*; sixfold axis, plane of symmetry perpendicular to this axis, a centre of symmetry.

It is possible that the crystal may belong to any of these three but it is impossible, at present, to limit its symmetry elements further.

* Supra.

Reflections of Cu K radiation were obtained by the Bragg method, from the basal section and from the two vertical sections *a* and *b*. Preliminary results only are available.

From measurements on these spectrum photographs of the basal plane it can be concluded that the spacing of planes parallel to the natural basal face is approximately 4.5 A.* From measurement on the spectrum photographs of vertical section *b*, the spacing of planes parallel to the prism face is approximately 6.3 A. From measurements on that of vertical section *a* it is approximately 3.05 A. This would be in approximate agreement with the result from section *b* if the first order spectrum from section *a* was considered to be missing for the spacing deduced from section *a* would become 6.1 A. This assumption is justifiable as the reflections from section *a* are extremely faint and it was observed on the spectrum photograph of section *b* that the first order reflection was weaker than the second order. It is conceivable that the first order reflection from section *a* was too weak to appear.

SUMMARY.

Simpsonite was found to belong to the hexagonal division of the hexagonal system. It possesses no higher symmetry than that given to it by the possession of a sixfold axis, a plane of symmetry at right angles to that axis and a centre of symmetry.

A preliminary value for the spacing of planes of atoms parallel to the basal face was found to be approximately 4.5 A. A preliminary value for planes parallel to a prism face is approximately 6.2 A.

ACKNOWLEDGMENTS.

These investigations were carried out in the Physics Department of the University of Western Australia during the tenure of a Commonwealth research grant for which the author wishes to express her thanks to the Council for Scientific and Industrial Research. From a separate grant from the same source the X-ray goniometer spectrograph and X-ray tubes used in the work were provided. The author wishes to express her thanks for the use of this apparatus and for the facilities provided by the Physics Department.

Specimens of simpsonite were kindly provided by the Government Mineralogist and Analyst, Dr. E. S. Simpson.

The work was carried out under the supervision of Mr. J. Shearer, of the Physics Department, to whom the author's thanks are due for valuable advice and criticism.

DESCRIPTION OF PLATE.

Reproductions of X-ray photographs in original size.

Fig. 1. Laue picture taken with X-ray beam perpendicular to the basal plane. Crystal to film distance 4.1 cms.

Fig. 2 Laue picture taken with X-ray beam perpendicular to prism face *a* Crystal to film distance about 5 cms.

Fig. 3. Laue picture taken with X-ray beam perpendicular to prism face *b* (adjacent face to *a*). Crystal to film distance = 4.0 cms.

*A = Angstrom unit = 10^{-8} cm.

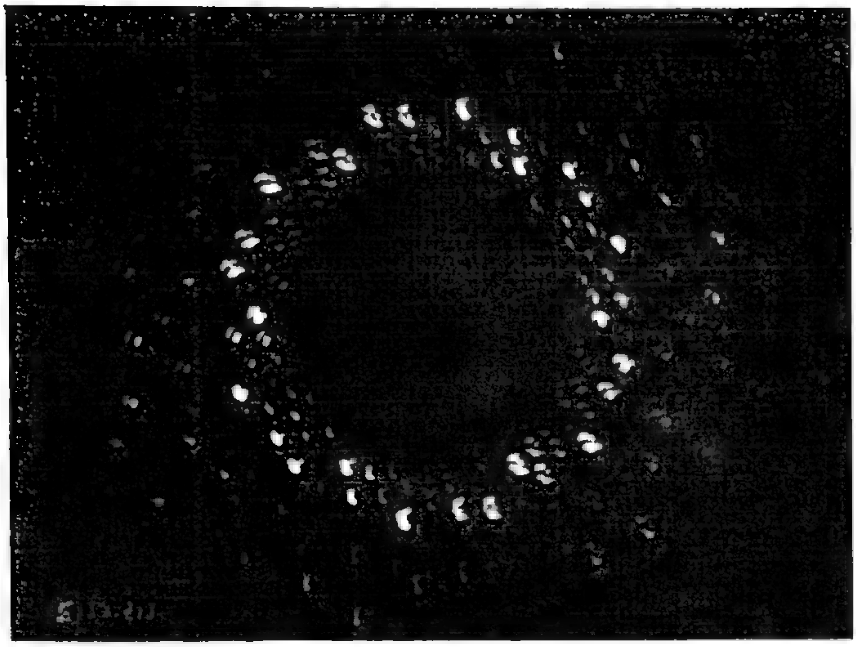


Fig. 1

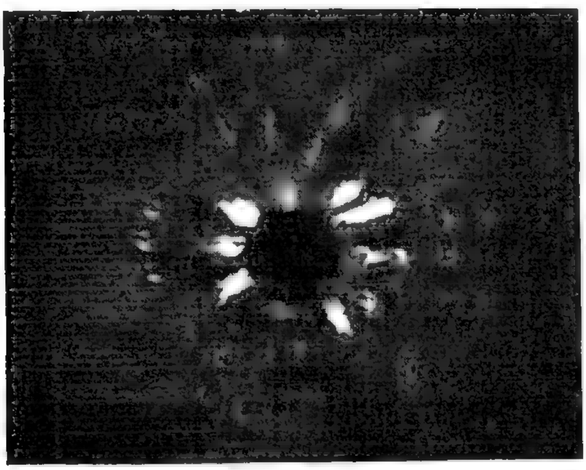


Fig. 2.

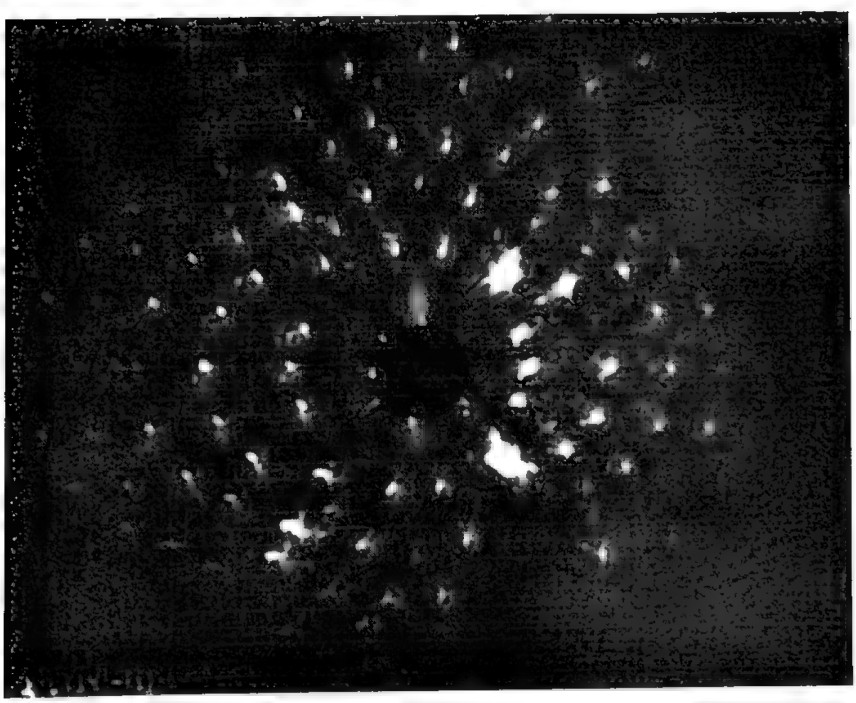


Fig. 3.

4.—A SECOND AUSTRALITE OBSERVED TO FALL IN WESTERN AUSTRALIA.

By

Edward S. Simpson, D.Sc., B.E., F.A.C.I.

Read, 13th September, 1938; Published, 26th June, 1939.

In October, 1934, I described the details of the observed fall of an australite in 1933 at Lake Grace, the first recorded observation of its kind. I now desire to record the entirely independent evidence of a second fall observed at Cottesloe, near Perth, in 1935.

Early in 1935 (the exact date is forgotten) Mr. F. Hanson was working on a gravel tennis court in Kathleen Street, North Cottesloe, when he heard, at about 10 or 11 a.m., a thud on the surface of the court. He observed a thin cloud of dust rising about 30 feet away, and found evidence of some object having penetrated the surface there. Digging on the spot immediately, he found beneath 3 inches of laterite gravel (used to surface the court) and a further 12 inches of loose sandy soil, a rounded stone weighing about 5 ounces, which was still too hot to hold in the hand. This stone he kept and showed to friends at various times, but not till early in 1938 did anyone see it who was able to suggest its probable nature and origin. This person urged the finder to see me, and as a result I have been able to collect what evidence there is regarding the fall, and to secure the specimen for the Western Australian Museum. As Mr. Hanson had never heard of an australite before, still less known that there was a record of an observed fall at Lake Grace, his evidence is entirely independent and unbiassed. The site of this fall is 180 miles in a direct line W.N.W. of Lake Grace.

The object itself is typical in every respect. (See Plate.) It is composed of homogenous black glass, only translucent in thin splinters. Its specific gravity is 2.42. The original weight of the body was about 156 grammes, but Mr. Hanson hit it with a hammer to see what it was composed of, and in doing so split thin flakes off two sides, leaving its present weight 154 grammes. The form is that of a lens with maximum and minimum diameters 57 and 55 mm., and maximum thickness 39 mm. A distinct equatorial ridge surrounds the greater part of the circumference at 24 mm. below the summit, the top half of the lens being as usual more sharply convex than the lower.

There is no sign of weathering or sand abrasion on the surface, which is covered with minute wrinkles and has a soft sub-vitreous lustre. The smooth outlines of the body are modified by many typical channels and conchoidal flake scars, but even on the surfaces of this secondary sculpturing, the finely wrinkled surface mostly persists. It would appear as if the chilled surface had spontaneously flaked, and subsequently been reheated to a point of slight fluidity to a very shallow depth. The channels or grooves, which average 1 mm. in width, are either straight, curved or completely annular. In the latter case they surround a small central projection, thus forming the "hofchen" of Suess. The grooves are marked by low cross ridges, typical of conchoidal fracture.

It is evident that the object seen to fall at Cottesloe is a typical australite in composition, texture and form.

By courtesy of Mr. J. B. Knight, an American who in 1934 was carrying out some mineralogical research in the British Museum of Natural History, I am able to present with the photographs of the Cottesloe australite, for which I am indebted to the Government Printer and Mr. B. L. Southern, one of the australite seen to fall at Lake Grace in 1933.

Ref. 1935. *Journ. Roy. Soc. W.A.*, 21, p. 37-8.

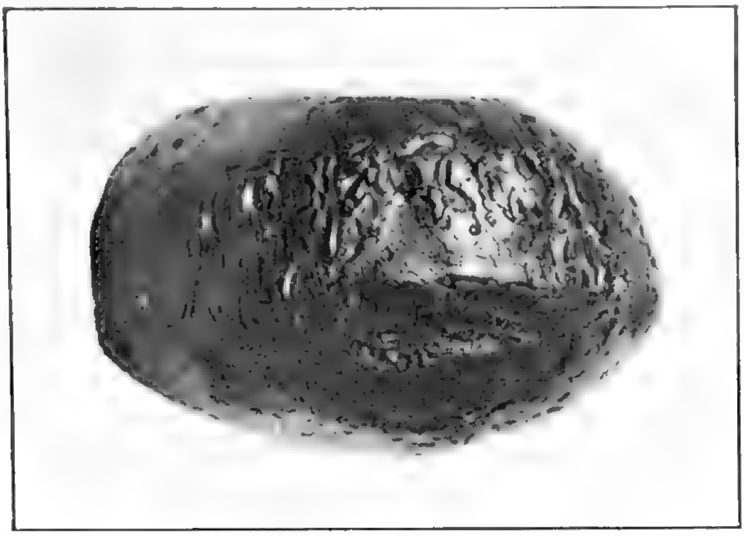


Fig. 1

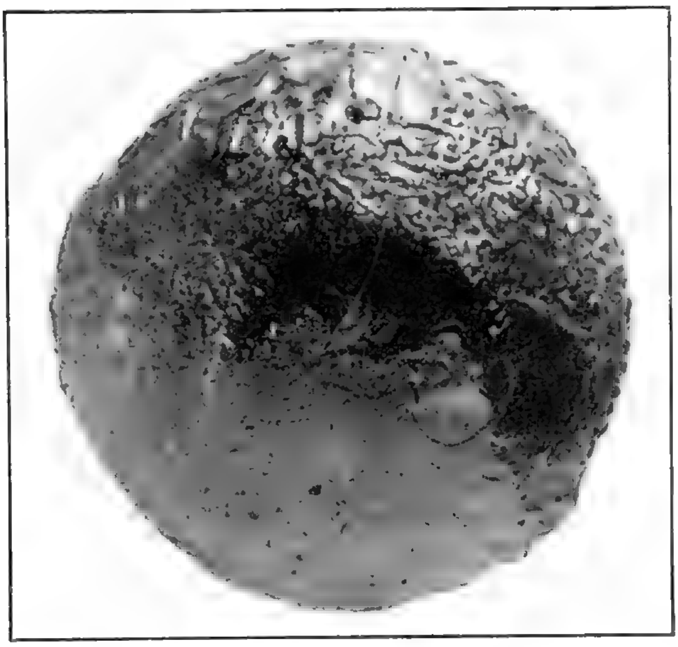


Fig. 2.

Fig. 3.

Figs. 1 & 2. Australite seen to fall at Cottesloe, 1935. Natural size. Photos., Government Printer and B. L. Southern.
Fig. 3. Australite seen to fall at Lake Grace, 1933. Twice natural size. Photo., J. B. Knight.

5.—NAUTILOID CEPHALOPODS FROM THE DEVONIAN OF WESTERN AUSTRALIA.

BY

CURT TEICHERT.

Read 13th September, 1938; Published 7th July, 1939.

CONTENTS.

ABSTRACT.

A brief review of the Devonian of Western Australia is given and attention is called to the unique position of the goniatite fauna in the Upper Devonian which is geographically far removed from any goniatite fauna of similar age. Actinosiphonate cephalopods, formerly not known outside Europe and North America, are for the first time shown to occur in Australia. The significance of the structures in this group is discussed and a classification of the group suggested. In this connection the following new families have been established: Diestoceratidae, Oocerinidae, Karoceratidae, Archiacoceratidae, Ptenoceratidae, Nothoceratidae. Furthermore, the significance of stereoplasmatic deposits in the camerae of certain cephalopods is discussed and attention is called to certain difficulties in classifying members of the Stereoplasmoceratidae.

The descriptive part contains the description of a new genus *Wadeoceras* as well as the description of new species of *Galtoceras* and *Stereoplasmoceras*, and of *Conostichoceras hardmanni* (Etheridge).

INTRODUCTION.

According to our present state of knowledge, Upper Devonian and presumably also Middle Devonian strata are represented in Western Australia, where they are known in patches along a narrow belt indicated by the Napier, Oscar and Rough Ranges on the south-western border of the Kimberley District, the northern topographic unit of Western Australia. Middle and early Upper Devonian strata are known from several localities in coral- and brachiopod-bearing calcareous facies (*Rough Range series* of Wade, 1938). Among the most important fossils of this division are: *Actinostroma*, *Stromatoporella*, *Disphyllum depressum*, *D. virgatum*, *Alveolites tumida*, *Aulopora repens*, *Atrypa aspera*, *A. desquamata*, *Schizophoria striatula*, *Wilsonia cuboides*, *Pugnax pugnus* (Hosking 1933, Hill 1936). Higher stages

of the Upper Devonian are represented by the *Mt. Pierre series* (Wade 1938), best known from the locality known as Mt. Pierre, where extensive collections of cephalopods, mainly goniatites, have been made.[1]

Cephalopods from Mt. Pierre were first mentioned by A. H. Foord, who, in 1890, briefly described poorly preserved specimens of "*Orthoceras*" and "*Goniatites*." Gürich, in 1901 (p. 515) suggested an early Upper Devonian age of the goniatites described by Foord, comparing them with *Goniatites simplex* (= *Tornoceras*) and *Goniatites calculiformis* (= *Manticoceras*) respectively. A consideration of the brachiopods described by Foord in the same paper led Haug (1911, p. 711) to infer the presence of Upper Devonian in Western Australia. However, the first actual proof of the occurrence of strata of this age was furnished by Delépine (1935) after a more detailed examination of collections of goniatites made by Professor Clarke and Dr. Wade. Delépine described the following species: *Sporadoceras contiguum* (Münster), *Pseudoclymenia australis* sp. nov., *Tornoceras* ? sp. nov., and *Dimeroceras clarkei* sp. nov. On the evidence of these species he concluded that the age of the Mt. Pierre strata must be Fammenian, most probably equivalent to Oberdevonstufe III.

In 1937, Schindewolf (p. 183) claimed that *Pseudoclymenia australis* and *Tornoceras* ? sp. nov. should be referred to *Protornoceras* Dybczynski.

The Goniatite limestone of Mt. Pierre is of remarkable interest, because it is so far removed from any other goniatite occurrence of similar age. There are no goniatites in the Devonian of the Tasman Geosyncline of Eastern Australia, where corals and brachiopods, though with European affinities, are predominant. The few facts which are known about the Devonian of New Guinea (Feuilletau de Bruyn 1921, p. 98; Stehn 1927; Teichert 1928, p. 6-13) show that the development there is mainly arenaceous with brachiopods and lamellibranchs. Similar types of deposits are represented in Burma, in the Yunnan, and in Tonkin. In fact the only Devonian goniatite fauna in eastern and south-eastern Asia is a small *Manticoceras* assemblage in the Chinese province of Hunan (Sun 1935) which is older than the goniatite beds of Mt. Pierre, and the nearest localities of goniatite faunas of approximately the same age as that of Western Australia are to be found in the southern Urals.

The brachiopod and coral facies of the Western Australian Devonian is more in harmony with the general development of the Devonian in South-eastern Asia, New Guinea and Eastern Australia. The age of the Devonian fossils of South-West New Guinea could be determined as Middle to early Upper Devonian (Teichert 1928) which corresponds to the age of the coral-brachiopod facies of the Kimberleys, as well as to that of the marine part of the Devonian section in Eastern Australia. Here, the uppermost part of the Devonian is represented by fresh-water beds and marine Fammenian also seems to be absent from New Guinea.

On the following pages, nautiloids from Mt. Pierre will be discussed and described, and, in addition, nautiloids from two other localities, viz., Lennard River and Oscar Homestead.

A cephalopod from Barker Gorge, Napier Range, listed as *Orthoceras* by Hosking (1933, p. 69) is identical with *Michelinoceras* cf. *schlotheimi* (Steininger) from Mt. Pierre. The rock containing this and the associated

[1] For details concerning the distribution of the Devonian outcrops in the Kimberley district the reader is referred to the summary by Lucy Hosking (1933).

brachiopod specimens listed by Hosking is very similar to the Mt. Pierre limestone. It is, therefore, probable that the Mt. Pierre Series also crops out in the Napier Range, although it may be developed in brachiopod facies in this place. It would be an interesting subject of future research to establish the exact correlation between the brachiopod and the goniatite facies in the Upper Devonian of Western Australia.

The distribution and age of the fossils described in the last chapter of this paper is as follows:—

Michelinoceras cf. *schlotheimi* (Steininger) Fammenian. Barker Gorge, Napier Range, and Mt. Pierre.

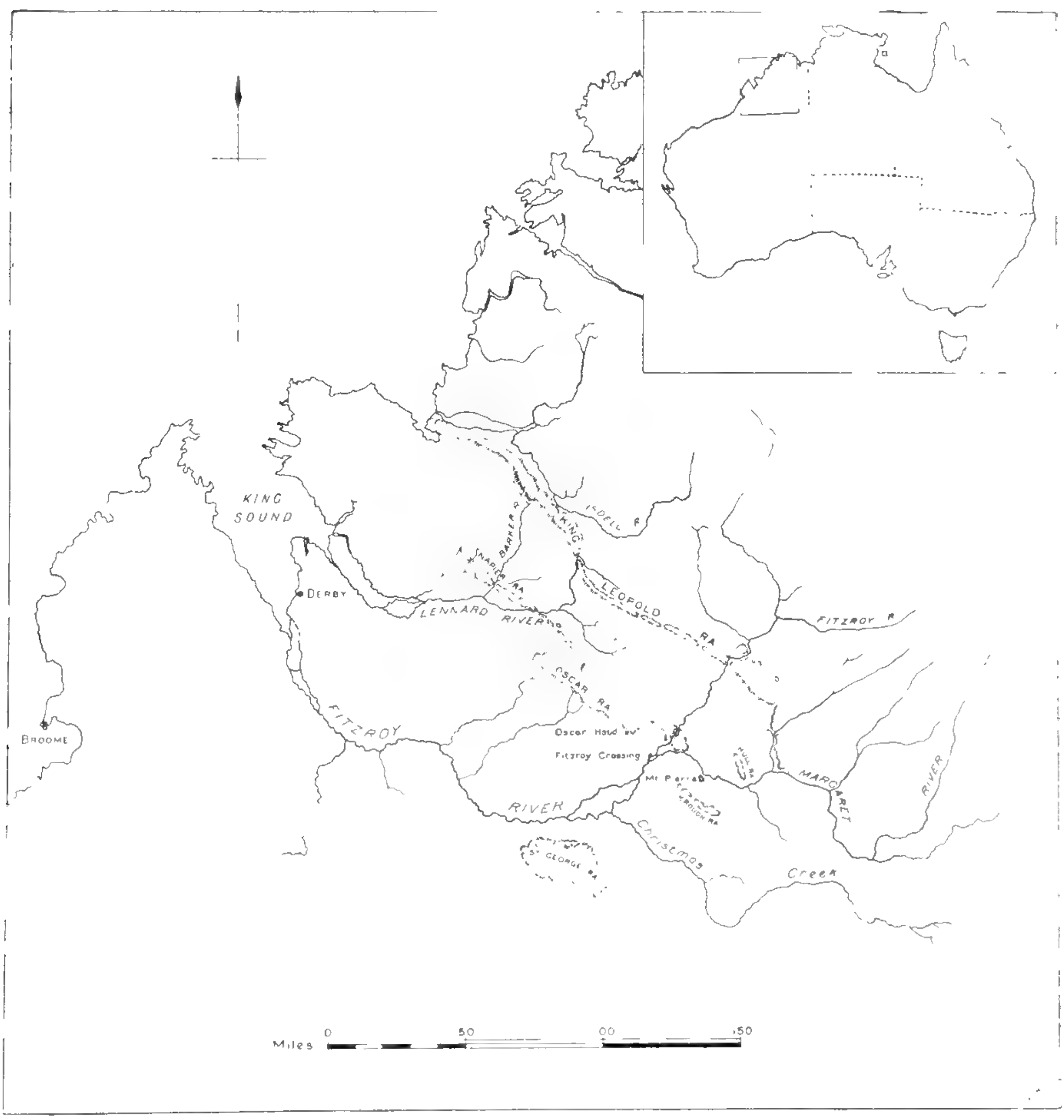
Stereoplasmoceras iniquiseptatum sp. nov. Probably Upper Devonian. Oscar Homestead, Oscar Range.

Wadeoceras australe gen. nov. et sp. nov. Fammenian. Mt. Pierre.

Conostichoceras hardmanni (Etheridge). Perhaps Middle Devonian. Lennard River, probably from the Napier Range.

Galtoceras kimberleyense sp. nov. Fammenian. Mt. Pierre.

The localities mentioned in the text can be found on the attached map (fig. 1).



OCCURRENCE OF CYRTOCEROIDEA (ACTINOSIPHONATE CEPHALOPODS) IN AUSTRALIA AND SUGGESTED CLASSIFICATION OF THIS GROUP.

Two of the species described in this paper, viz. *Wadeoceras australe* n. sp. and *Conostichoceras hardmanni* (Etheridge), belong to a group of cephalopods which is usually known as the actinosiphonate group and which so far has not been recorded from Australia. It is true that the cephalopod described by Etheridge in 1897, clearly shows the actinosiphonate structure, but its affinities were not recognised by that author and the specimen was described as an *Actinoceras*.[1]

Wadeoceras australe occurs in the Mt. Pierre limestone and is, therefore, presumably of the Fammenian age, whereas the specimen of *Conostichoceras* comes from an unknown locality on the Lennard River. Etheridge assigned a Carboniferous age to this latter specimen, but cephalopods of the actinosiphonate group can hardly be expected in rocks of that age. In his elaborate study of actinosiphonate cephalopods, published in 1926, A. F. Foerste (p. 288) stated that "the Actinosiphonata are known to range from the lower Upper Ordovician to the Upper Devonian. Possibly they occur in the Carboniferous, but the evidence is not clear." The latter statement refers to the structure of *Orthoceras breynii* Martin from the Carboniferous of England which, however, according to Foerste's statement on p. 290 of the same paper "is regarded as actinoceroid rather than actinosiphonate." All the facts concerning this species have been presented and discussed by Miller, Dunbar and Condra in 1933 (p. 54-57) and nothing in their discussion indicates the presence of actinosiphonate structures within the siphuncle of the holotype.[2] These authors have reproduced Martin's original figure of *Orthoceras breynii* and as far as can be judged from this picture, there is no indication of actinosiphonate lamellae within its siphuncle. Thus, in the present state of knowledge, it is only possible to say that actinosiphonate cephalopods do not range higher than the Upper Devonian.

In regard to the geographical distribution of the Actinosiphonata Foerste has pointed out (1926, p. 291-292) that they are found throughout Europe (including Novaya Zemlya) and in the eastern and mid-western states of North America. No species have so far been recorded from Asia. The occurrence in Australia of representatives of this group is, therefore, of considerable interest. The group may also be represented in the Middle Devonian of Victoria and Queensland by *Phragmoceras subtrigonum* McCoy, but this requires further corroboration.

So far, *Conostichoceras* had only been described from the Middle Devonian of Bohemia but it must be remembered that the study of Devonian nautiloids in Europe has been neglected for decades and that their vertical distribution, therefore, is probably very incompletely known.

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[1] The occurrence of *Actinoceras* in rocks of post-Silurian age has also been reported in the Yunnan by Reed (1927, p. 16) and in New Guinea by Martin (1911, p. 93) and by the present writer (1928, p. 17). These references, however, will have to be changed. No true actinoceroids are known from any of these places.

[2] It should be noted that *Orthoceras breynii* Martin has been selected as genotype of *Loxoceras* McCoy by Bassler in 1915 (p. 767) and that, therefore, *Breynioceras* Foerste (1929, p. 284) is an exact synonym of *Loxoceras*, as it has the same genotype.

The specimen of *Conostichoceras hardmanni,* however may be derived from strata of Middle Devonian age. The Lennard River crosses the Napier Range, where outcrops of Devonian strata are known to occur. Hosking (1933, p. 68-69) mentions numerous brachiopods, *Proetus, Euomphalus,* and *Bellerophon* from two different localities in the Napier Range, and Hill (1937, p. 30) has described *Phillipsastraea delicatula* from Barker Gorge, Napier Range, a species closely related to the Upper Devonian *P. hennahi,* but the occurrence of Middle Devonian in this country is at least not contradicted by fossil evidence.

Cephalopods with an actinosiphonate structure of the siphuncle were grouped in a separate order, Cyrtoceroidea, by the present writer in 1933. Schindewolf (1935, p. 110), though recognising the validity of the group, would prefer to class it as a suborder of the Nautiloidea. Eighty species, belonging to 41 genera, were enumerated by Foerste in his "List of known Actinosiphonata" in 1926 (p. 303-304). Since then a number of additional species have been described by Troedsson, Heritsch, Strand, Flower, and the present writer, bringing the number up to the vicinity of hundred and extending the geographical range northward to Greenland. The Cyrtoceroidea as defined by the present writer include orthoconic, cyrtoceraconic and coiled conchs in a great variety of forms, comparable to the variety in other cephalopod groups.

Foerste has called attention to the difficulty in classifying certain forms which are very similar to actinosiphonate genera, but in which no endosiphuncular structures are known. Until more is known of these forms, they are better excluded from the Cyrtoceroidea. If only genera in which actinosiphonate structure is known to occur, are considered, the following classification can be suggested:—

Family Jovellanidae Foord. Orthoconic conchs.
Lamottoceras Foerste, *Jovellania* Bayle, *Mixosiphonoceras* Hyatt, *Tripleuroceras* Hyatt, *Projovellania* Hyatt.

Family Diestoceratidae nov. Brevicones, either straight or slightly curved.
Diestoceras Foerste, *Wetherbyoceras* Foerste, *Herkimeroceras* Foerste, *Pachtoceras* Foerste.

Family Oocerinidae nov. Longiconic cyrtoceracones.
Oocerina Foerste, *Blakeoceras* Foerste, *Perimeroceras* Foerste.

Family Karoceratidae nov. Exogastric cyrtoceracones without constricted aperture.
Karoceras Roussanoff, *Wissenbachia* Foerste, *Conostichoceras* Foerste, *Turnoceras* Foerste, *Poteriocerina* Foerste, *Minganoceras* Foerste, *Eleusoceras* Flower.

Family Cyrtoceratidae Chapman. Exogastric cyrtoceracones with constricted aperture.
Cyrtoceratites Goldfuss,[1] *Amphicyrtoceras* Foerste, *Paracleistoceras* Foerste, *Acleistoceras* Hyatt, *Brevicoceras* Flower, and perhaps *Cyrtactinoceras* Hyatt.

[1] This genus is usually referred to as "*Cyrtoceras* Goldfuss" and credited to this author as a manuscript name first published in de la Beche's "Handbuch der Geognosie" in 1832 (p. 536). Actually, however, the name was written *Cyrtocera* in this publication, but it is preceded by *Cyrtoceratites* Goldfuss which was published as a manuscript name by F. Hoeninghaus in 1830 (p. 228). Goldfuss himself used still another spelling in 1832 (p. 483), viz., *Cyrthoceratites.* The name *Cyrtoceras* was first used by Sowerby in 1839 (p. 621) in connection with a gastropod ("*Cyrtoceras laeve*").

Family Archiacoceratidae nov. Endogastric cyrtoceracones.

Endoplectoceras Foerste, *Archiacoceras* Foerste,[1] *Danaoceras* Foerste, *Codoceras* Hyatt, *Coelocyrtoceras* Foerste, *Wadeoceras* nov. gen. Perhaps also *Protophragmoceras* Foerste.

Family Phragmoceratidae Hyatt. Phragmoceroid conchs, mostly endogastric, aperture with dorsal or lateral sinuses.

Phragmoceras Broderip, *Bolloceras* Foerste, *Tubiferoceras* Hedström, *Mandaloceras* Hyatt, *Hemiphragmoceras* Hyatt, *Tetrameroceras* Hyatt, *Conradoceras* Foerste, *Paraconradoceras* Foerste, *Hexameroceras* Hyatt, *Octameroceras* Hyatt, *Metaphragmoceras* Flower.

Family Ptenoceratidae nov. Trochoceroid conchs.

Ptenoceras Hyatt, *Adelphoceras* Barrande, *Homoadelphoceras* Foerste.

Family Nothoceratidae nov. Nautiloid conchs.

Lorieroceras Foerste, *Nothoceras* Barrande.

REMARKS ON THE STEREOPLASMOCERATIDAE.

One of the Western Australian forms has been described below as *Stereoplasmoceras iniquiseptatum* and, since the group to which this species belongs, has been recently discussed by Kobayashi (1936), a few remarks considering this group may be appropriate. It is now generally recognised by most authors that stereoplasmatic deposits exist in the camerae of many nautiloid cephalopods, especially in orthoceraconic forms. Observations on these deposits were first made and communicated by Barrande in 1859. Since then, numerous authors, including Dewitz, J. Hall, H. Schröder, G. Holm, Graubau, and Miller, Dunbar and Condra, have discussed these structures and the present writer, in 1933, has given a full account of intracameral deposits in actinoceroid cephalopods and also discussed their presence in certain non-actinoceroid forms. As far as the origin of these deposits is concerned, most authors seemed to adhere to Barrande's original view that they were formed after the formation of the septum to which they belong, and before the formation of the next succeeding septum. An alternative explanation had been to assume that the material for the intracameral deposits had been supplied by the siphuncle through foramina in the connecting ring. The first idea does not account for the formation of hyposeptal deposits and for the regularity of increase in thickness of the deposits in many forms; the second idea was disproved by the fact that

[1] It could perhaps be argued whether the name *Phragmoceratites* d'Archiac and de Verneuil should not take precedence over *Archiacoceras* Foerste. D'Archiac and de Verneuil, when establishing *Phragmoceratites subventricosus* in 1842 (p. 351), were the first authors to use the generic name *Phragmoceratites*. However, from their text it is quite evident that they did not want to establish *Phragmoceratites* as a generic name, but merely wanted it to replace *Phragmoceras* Broderip. Since Art. 25 of the International Rules provides that none of the earlier names should be available unless it is "accompanied by an indication, or a definition, or a description," I do not think that d'Archiac and de Verneuil established a genus "*Phragmoceratites*," even if, as it appears to be the case, *subventricosus* is the only species ever described in connection with this generic name. Because *Phragmoceratites* has only been substituted for *Phragmoceras*, the genotype of the latter becomes automatically the genotype of the former, and that name must be suppressed as a synonym.

the connecting ring is not perforated by macroscopical openings and it was shown by the present writer in 1933 that the material necessary for the formation of intracameral deposits must have permeated through the connecting ring in some other way.[1]

There is no doubt that the Stereoplasmaceratidae[2] which, as defined by Kobayashi in 1936, include genera with intracameral stereoplasmatic deposits either with or without an endosiphuncular stereoplasmatic tube, are members of an important group of cephalopods and may even have higher than family rank. However, in spite of the importance which on account of their wide distribution, must be attached to the presence of these intracameral deposits, it is still necessary to take great care in the grouping of forms with these characters. In 1933, the writer asked the question, what taxonomic importance should be attributed to the presence of intracameral deposits. To-day, the question would be better put by asking, what taxonomic importance should be attributed to the *absence* of these deposits. Kobayashi does not discuss the significance of the fact that we find species with intracameral deposits and species without such deposits belonging to one and the same genus of actinoceroids. In the case of actinoceroid cephalopods we have criteria other than intracameral deposits to ascertain the generic affinities of species, but in cephalopods lacking distinctive features of the siphuncle, it becomes almost impossible to tell how species agreeing with stereoplasmoceroids in all other respects should be classified if they lack intracameral deposits. Evidently, the absence of these deposits might be just as accidental and insignificant in stenosiphonate forms as it can be in actinoceroids, and although their presence must be regarded as of considerable biological interest, the taxonomic significance of their absence in certain cephalopods is still far from being sufficiently understood.

Stereoplasmoceras iniquiseptatum, described below, represents a development of stereoplasmoceroids which is characterised by small "obstruction rings," better called bullettes, in the vicinity of the septal necks. The combination of bullettes with intracameral deposits is characteristic of many cephalopods and is also found in orthochoanitic forms with cylindrical segments of the siphuncle. As an example, a specimen can be mentioned which was described as "*Orthoceras* n. sp." by the present writer in 1933 (p. 182). Very similar types are numerous in the Silurian and Devonian of Bohemia, e.g. *Orthoceras jonesi* (Barrande 1859, pl. 18, fig. 13). Among the species with slightly inflated segments the Devonian *Orthoceras concors* and the Silurian *Orthoceras vibrayei* may be mentioned (Barrande 1859, pl. 18, figs. 6 and 9).[3]

[1] Kobayashi, in 1936 (p. 231), erroneously ascribed to the writer the view that "the pseudosepta or the junction of the deposits from both sides of the camera, is naturally united with the opening of the diverticula." The writer, on the contrary, has devoted many pages to an attempt to prove that the "diverticula" or radial canals of the siphuncle are not in open communication with the camerae, but open into the perispatia, that the connecting ring is not perforated by foramina, and that the "pseudoseptum" is not an organic structure at all, but the contact surface between episeptal and hyposeptal deposits.

[2] The genus *Pseudorthoceras* Girty which was included in the *Stereoplasmoceratidae* by Kobayashi in 1936, constitutes, together with related Late Palaeozoic genera, the family Pseudorthoceratidae Flower and Caster.

[3] Many more examples could be quoted from Barrande's "Système Silurien," but unfortunately this work is not available in Western Australia.

All these forms have essentially the same structure, viz., small bullettes in the siphuncle and intracameral deposits, and should be grouped together in spite of the differences in the shape of the segments and in the structure of the septal neck. It is obvious that this group is not related to the actinoceroids, because in the latter the "stereoplasmatic deposits" within the siphuncle originate by a process of progressive calcification of an originally soft, endosiphuncular tissue in which the endosiphuncular vascular system is embedded.

DESCRIPTION OF THE SPECIES.

FAMILY **ORTHOCEROTIDAE.**

Genus **MICHELINOCERAS** Foerste.

Michelinoceras cf. **M. schlotheimi** (Steininger).

1890—Orthoceras sp. A. H. Foord, Geol. Mag., dec. III., vol. 7, p. 6, plate 4, fig. 3.

The Red Goniatite limestone of Mt. Pierre contains numerous specimens of a species of long orthoconic, slowly tapering conchs of orthoceroid cephalopods which, however, are not sufficiently well preserved for accurate description. The cross-section of the conchs is circular and the small, cylindrical siphuncle is central. The distance between the septa equals about 4/10 to ½ the diameter of the camerae. The length of full-grown specimens must have been something like 20 cm., almost half of which was occupied by the living chamber which was at least eight times as long as it was wide at its base. The rate of tapering is about 1 : 15.

The species known as *Orthoceras schlotheime* from the Frasnian (Zone 8) of Saltern Cove in England and from the Büdesheimer Schiefer of Germany (see Anniss, 1928) seems to be rather close to the Mt. Pierre form. Foord (1888, p. 97-98) described this species as "straight, extremely slender, cylindrical, very slowly tapering. Length of body-Chamber at least eight times the diameter of its base. Septa distant from about ½ to ⅗ the diameter." As long as no well-preserved internal moulds as well as traces of the test are known from Mr. Pierre, exact determination of the species will be impossible.

The same species apparently occurs also in the red limestone of the Barker Gorge, Napier Range.

FAMILY **MAELONOCERATIDAE** HYATT.

Genus **GALTOCERAS** Foerste.

Galtoceras kimberleyense sp nov.

Plate I., figs. 4, 5.

Diagnosis: Species differing from other members of the genus in the more rapid expansion of the phragmocone.

Description of holotype: The holotype and only known specimen is a portion of a moderately curved exogastric phragmocone; its dorso-ventral diameter at the adapical end is 10 mm., the lateral diameter 12 mm. At the adoral end the dorso-ventral diameter is 20 mm., whereas the lateral diameter cannot be accurately determined. The length of the camerae increases from 2 mm. at the adapica end to 2.8 mm. at the adoral end of the specimen. The sutures are straight and directly transverse to the curving longitudinal axis of the conch. The siphuncle is close to the convex side of the conch. The segments are narrow and cylindrical, being only slightly constricted at the septal foramina.

Locality: Mt. Pierre, Western Kimberley District, Western Australia. No. 116 Commonwealth Palaeontological Collection, Canberra.

Remarks: The state of preservation of this specimen is rather poor, no trace of the shell being preserved. In *Galtoceras* the shell is finely striated transversely and in the holotype of *Galtoceras arcticameratum* Clarke and Ruedemann, kept in the New York State Museum, Albany, N.Y., the writer observed very shallow longitudinal ribs, when he had an opportunity of studying this specimen in 1930. Only Silurian species of Galtoceras are known so far, but the Australian species is referred to this genus on account of the slight curvature of the conch and the straight sutures which distinguish this genus from nearly related genera as e.g. *Cyrtorizoceras*.

The specimen has previously been figured by A. Wade in 1924 (p. 44, plate III.) and has been listed as *Geisonoceras* sp. by F. Chapman (p. 7 of undated pamphlet; see bibliography).

Cyrtoceras cornu-copiae Sandberger and *Cyrtoceras bilineatum* Sandberger from the German Devonian may be related species, but so far too little is known about their structure (see Sandberger 1855, plate 13, fig. 4 and plate 14, fig. 2).

Family **ARCHIACOCERATIDAE** nov.

Genus **WADEOCERAS** gen. nov.

Genotype: **Wadeoceras australe** sp. nov.

Slightly compressed, endogastric cyrtoceracones with actinosiphonate siphuncle. The segments of the siphuncles are wider than long, but not inflated between the septa.

This genus is very similar externally to *Danaoceras* Foerste as well as to *Archiacoceras* Foerste. In the former genus, however, which is known from the Middle Silurian of Bohemia the siphuncle is very narrow and cylindrical, whereas in the latter genus, known from the Middle Devonian of the Eifel, Germany, the siphuncle is broadly nummuloidal (Foerste, 1929, p. 295).

Phragmoceras subtrigonum from the Middle Devonian of Victoria and Queensland may belong to this genus or to *Archiacoceras*. In his description of this species McCoy (1876, p. 18) mentioned its similarity to *Phragmoceras subventricosum* d'Archiac and de Verneuil which is the genotype of *Archiacoceras*, but the structure of the siphuncle of *Phragmoceras subtrigonum* is still unknown.

Wadeoceras australe sp. nov.

Plate I., figs. 2, 3. Text-fig. 1.

Diagnosis: Slightly compressed endogastric cyrtoceracone, with actinosiphonate structure of siphuncle.

Description: The holotype and only specimen known is a portion of a phragmocone, 57 mm. long. It increases rapidly in diameter, the cross-section being compressed laterally. At the adapical end the dorso-ventral diameter is about 32 mm., the lateral diameter about 24 mm. At a distance of 40 mm. from the adapical end the dorso-ventral diameter is 51 mm., whereas the lateral diameter is 45.5 mm. The outline of the dorsal side of the phragmocone is slightly convex, whereas the ventral side which is not very well preserved seems to be almost straight, although a median longi-

tudinal section reveals a slight curvature of the siphuncle in the adapical part of the specimen, so that the conch had a slightly concave outline along the posterior part of the ventral side.

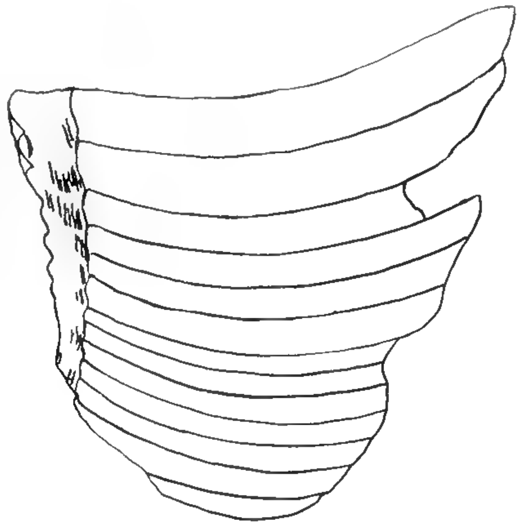

Fig. 1.—Dorso-ventral section of holotype of *Wadeoceras australe*. Nat. size.

The sutures rise dorsally and, owing to the curvature of the dorsal side, the distance between two sutures in the middle part of the specimen increases from 2 mm. on the ventral side to 5 mm. on the dorsal side. The septa are rather deeply concave, being 6 to 7 mm. deep.

The siphuncle is very probably not more than 1 or 2 mm. from the wall of the conch. The septal necks are cyrtochoanitic on the ventral side and orthochoanitic on the dorsal side. The width of the septal foramen increases from 2.5 mm. in the adapical part to 6 mm. in the adoral part of the specimen. A peculiarity of the segments of the siphuncle is their lack of symmetry. In the dorso-ventral section the ventral outline is convex, whereas the dorsal outline is concave. The curvature of the outlines on both sides is approximately equal and the width of the segments, therefore, is approximately equal to the width of the corresponding septal foramina. In the interior of the siphuncle there are numerous radiating lamellae which apparently are not continuous, but are restricted to the neighbourhood of the septal necks.

Locality: Mt. Pierre, Western Kimberley District, Western Australia. No. 117 Commonwealth Palaeontological Collection, Canberra.

Remarks: This specimen has been previously figured by A. Wade in 1924 (p. 42, plates II. and III.) and has been listed as *Rizoceras* sp. by Chapman (p. 7 of undated pamphlet; see bibliography).

FAMILY **KAROCERATIDAE** NOV.

Genus **CONOSTICHOCERAS** Foerste.

Conostichoceras hardmanni (Etheridge).

Plate I., fig. 1; Plate II., figs. 7, 8.

1897—*Actinoceras hardmanni*, R. Etheridge, Actinoc. N.-W. Australia, p. 7-9, pl. III.

Description: The holotype and only known specimen represents a portion of an exogastric phragmocone, being 155 mm. long and elliptical in cross-section. At the adapical end of the specimen the lateral diameter is

53 mm., whereas the dorso-ventral diameter is 37 mm. in the middle of the specimen the corresponding figures are 87 mm. and 49 mm. The lateral diameter at the adoral end of the specimen is 107 mm. It is, however, obvious that the specimen in its present state of preservation is more depressed than it was in its original state. It can be seen in transverse and longitudinal sections that the septa are crushed, but it is not possible to state the exact amount of secondary compression the specimen has suffered. However, because the ventral side is broadly and evenly rounded, whereas the lateral sides are narrowly rounded, it can be said that the phragmocone, at least in its posterior part, has had a rather broadly elliptical cross-section. The longitudinal outline of the ventral side of the specimen is evenly convex. Owing to the partial destruction of the dorsal side, it cannot be stated with certainty whether this was convex, straight, or concave; the latter, however, is the most probable. In the adoral part of the specimen the surface of the mould is distinctly elevated along a median longitudinal zone, where the siphuncle is situated. This elevation which is not visible in the adapical portion of the phragmocone is, however, probably due to resistance offered by the siphuncle when the specimen was compressed dorso-ventrally during fossilization.

The distance between two successive septa increases from 5 mm. in the adapical to 8 mm. in the adoral part of the specimen when measured along the ventral side. The sutures in the adapical part are straight, but in the adoral part they cross the ventral side in broad arches, the ventral lobes being 13 mm. high.

The siphuncle is situated 5 to 6 mm. from the ventral wall of the conch. Its actinosiphonate structure has been clearly illustrated by Etheridge. Between the radiating lamellae the lumen of the siphuncle is filled with limestone matrix, whereas the camerae are filled by infiltrated crystalline calcite. The cross-section of the siphuncle, reproduced on Plate II., Fig. 8 of this paper is taken approximately in the middle of the specimen, where the width of the siphuncle is 9.2 mm. laterally and 7.5 mm. dorso-ventrally. In this section there are 19 septa-like lamellae of varying length,

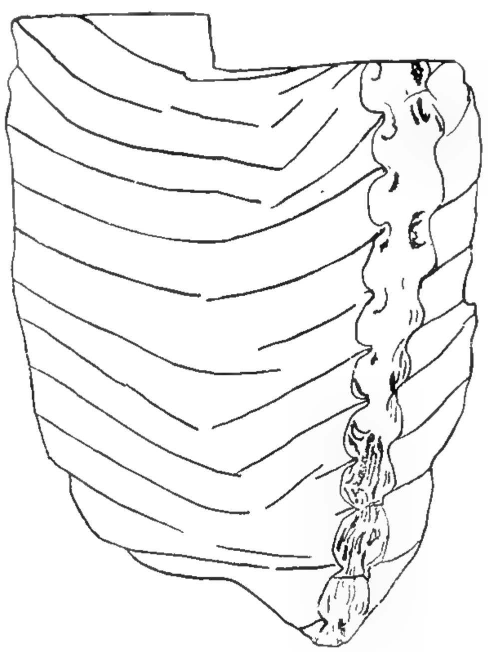

Fig. 2.—Dorsoventral section of holotype of *Conostichoceras hardmanni*. Nat. size.

radiating from the periphery of the segment towards the centre. Some of the lamellae are slightly thickened at their interior terminations. As Etheridge correctly observed, some of the lamellae appear to be folds of the connecting ring. In others this is not so clearly visible they simply seem to be processes extending from the inner side of the connecting ring. Colour and state of preservation of these lamellae is apparently the same as that of the connecting ring and it may be concluded that the lamellae consisted of a substance similar to that of the connecting ring. This possibility has already been suggested by the present writer after a study of Ordovician actinosiphonate *Diestoceras* (Teichert 1934, p. 45).

The shape of the segments of the siphuncle is somewhat irregular. The septal necks are orthochoanitic and long on the ventral side of the septal foramen, strongly cyrtochoanitic and much shorter on the dorsal side. Together with the similar though reversed conditions in *Wadeoceras australe* this affords additional examples of the variability of septal necks in one and the same specimen and for the unreliability of the shape of the septal neck as a criterion in classification.

As a rule, the ventral wall of the segments of the siphuncle is approximately straight or only slightly convex and vertical to the septa, forming the continuation of the straight septal neck. In the adapical part of the specimen this side of the wall of the segments is in contact with the adoral surface of the septa, the width of the adnation surface varying between 1 and 2 mm. On the dorsal side the segmental wall usually expands rapidly. In the adapical part of the specimen this dorsal side of the segments is slightly concave in the vicinity of the septal neck, then becomes convex, reaching the maximum convexity in the posterior third of the segment. Near the adapical septum the wall is strongly recurved and there is no adnation surface, the wall joining the septum at the septal foramen. As a rule, the segments have their maximum width in the posterior part. Lateral sections are available of two segments only. The septal neck in the lateral section apparently is still cyrtochoantic, though with a much less recurved brim than on the dorsal side of the foramen. Of the two segments one has the greatest width behind the middle, whereas in the other the wall is evenly convex.

Locality: Leonard River, Western Kimberley District, Western Australia. No. F.4600 Australian Museum, Sydney.

Remarks: This species agrees sufficiently well with *Cyrtoceras palinurus* Barrande, the genotype of *Conostichoceras* Foerste, to be included in this genus. It resembles the genotype in the general shape of the conch F, the position and size of the siphuncle and in, although in the holotype of *C. Palinurus* (reproduced by Foerste, 1926, plate 38, figs. 1A, 1B) a large part of the conch is occupied by the living chamber. It differs in the somewhat more irregular shape of the segments of the siphuncle and in lacking the slight concavity of the dorsal outline of the conch in the adoral part, and probably also in the smaller number of radiating lamellae within the siphuncle. The lateral view of the siphuncle of *C. palinurus*, as published by Barrande, shows that the segments of siphuncle of this species in a lateral section are much wider posteriorly than anteriorly and that they are adnate to the adoral surface of the posterior septum.

When he established the genus *Conostichoceras*, Foerste (1926, p. 341) called attention to the actinoceroid appearance of the segments of the siphuncle—a fact which is also apparent in *Conostichoceras hardmanni* and which misled Etheridge in referring this species to *Actinoceras*.

FAMILY STEREOPLASMOCERATIDAE KOBAYASHI.

Genus STEREOPLASMOCERAS Grabau.

Stereoplasmoceras iniquiseptatum sp. nov.

Plate I., fig. 6.

Description: The holotype is a portion of an internal mould of a phragmocone, 60.5 mm. long, approximately circular in cross-section with a diameter increasing from 26.5 to 32.5 mm. Externally the specimen is strongly weathered, but the internal structures are well preserved. There are ten camerae which are peculiar by their unequal length. The lengths of the camerae, starting with the posterior camera, are: 5.2, 4.5, 5.0, 8.3, 6.6, 6.1, 6.5, 6.1 and 7.8 mm. This is a very remarkable deviation from the constant increase in length of the camerae which is usually so characteristic of cephalopods of any group. The septa are moderately concave, being about 7 mm. deep. There are episeptal deposits as well as hyposeptal deposits within the camerae. These are more strongly developed on one side than on the other, probably indicating ventral and dorsal side of the specimen respectively. On neither side do the deposits extend to the siphuncle, but cover only part of the surface of the septa. The septal necks are cyrtochoanitic and between 0.7 and 1.0 mm. long. The brim is directed obliquely backward.

The siphuncle is central. Notwithstanding the difference in length of the segments (corresponding to the length of the camerae), all of them are inflated between the septa to the same width of 6.0 to 6.5 mm. Thus, the shorter segments have a more globular, the longer segments a more fusiform appearance. The septal foramina have a width of about 2.5 mm., but at the passage through the foramina the siphuncle is further constricted by small bullettes which extend around the septal necks. These bullettes are thinnest in the septal foramen, they expand slightly adorally as well as adapically. The remainder of the siphuncle has been empty, at least no traces of any other primary structures can be seen.

Locality: Near Oscar Homestead, south-eastern end of Oscar Range, western Kimberley District, Western Australia associated with *Spirifer verneuili*, an Upper Devonian species. No. 15702 Dept. of Geology, University of Western Australia.

Remarks: The remarkable inequality of the length of the camerae which has been mentioned above, is rarely found in Cephalopods. A specimen showing similar conditions has been figured by Kobayashi (1934, plate 24, fig. 1) as *Stereoplasmoceras tofangioides*. The following measurements for the length of 5 consecutive camerae have been taken from that figure: 7.3, 9.5, 7.0, 8.2, 8.2 mm. This specimen comes from the Middle Ordovician of Korea. It is not yet known, whether the changes in length of the camerae are a constant feature of certain species or an abnormal condition in individual specimens.

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EXPLANATION OF PLATES.

Plate I.

Fig. 1.—*Conostichoceras hardmanni* (Etheridge). Lateral view of holotype. (Upper part strongly compressed.) Devonian. Lennard River, Kimberley District. 0.8 nat. size.

Figs. 2, 3.—*Wadeoceras australe* gen. nov. et sp. nov. Dorsal and lateral view of holotype. Upper Devonian. Mt. Pierre, Kimberley District. Nat. size.

Figs. 4, 5.—*Galloceras kimberleyense* sp. nov. Lateral and ventral view of holotype. Upper Devonian. Mt. Pierre, Kimberley District. Nat. size.

Fig. 6.—*Stereoplasmoceras iniquiseptatum* sp. nov. Longitudinal median section of holotype. Devonian. Oscar Homestead, Kimberley District. Nat. size.

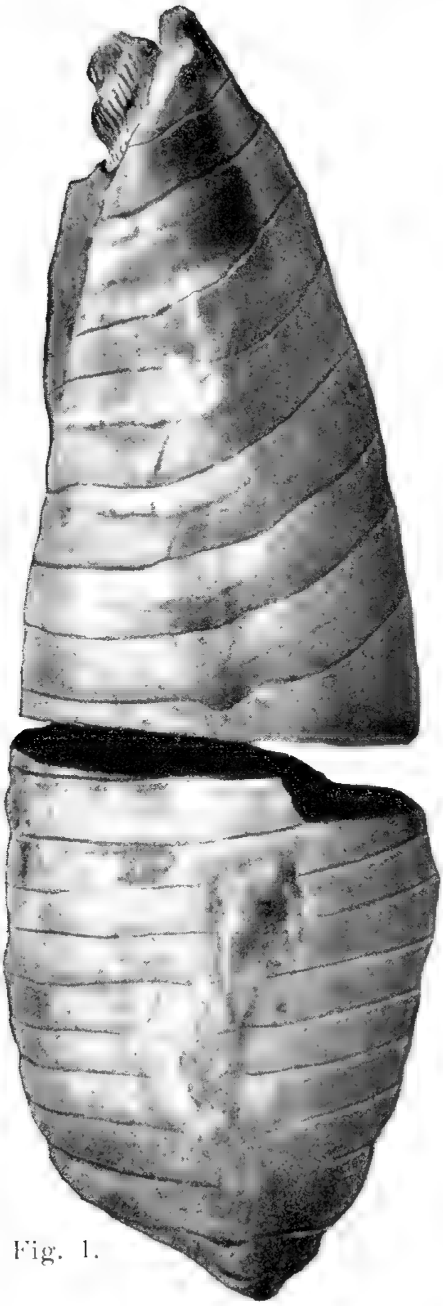

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

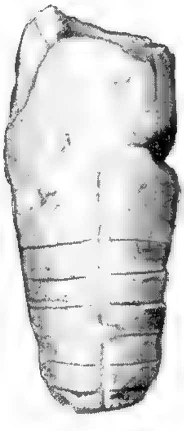

Fig. 5.

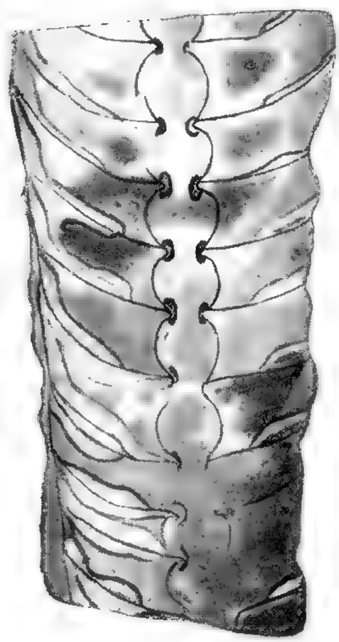

Fig. 6.

PLATE I.

Plate II.

Figs. 7, 8.—*Conostichoceras hardmanni* (Etheridge).

Fig. 7.—Ventral view of holotype (see Plate I., Fig. 1). 0.8 nat. size.

Fig. 8.—Cross-section of ventral part with siphuncle. 2.75 nat. size.

Fig. 7.

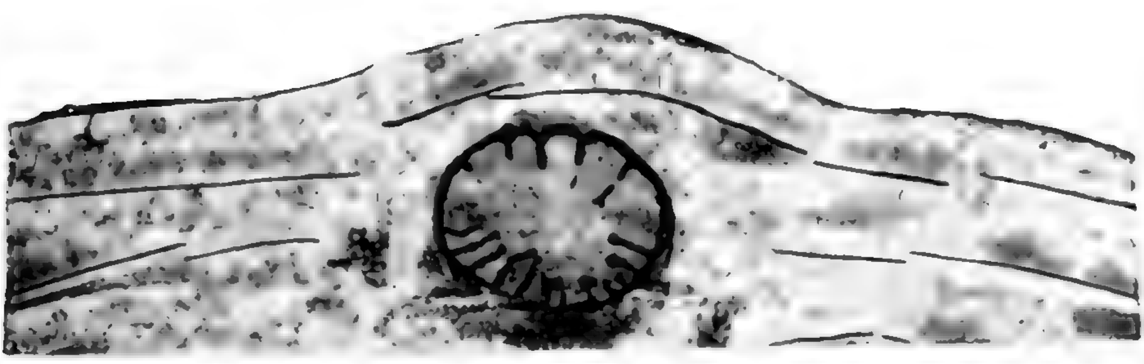

Fig. 8.

PLATE II.

6.—ON JURASSIC AMMONITES FROM WESTERN AUSTRALIA.

BY

L. F. Spath.

Communicated by Curt Teichert.

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CONTENTS.

INTRODUCTION.

The majority of the Western Australian ammonites described by Neumayr[1] and Crick[2] have always seemed to me rather unusual and different from European species of the Bajocian; and I was glad to receive, through the kindness of Professor E. de C. Clarke of the University of Western Australia, Crawley, a small assemblage of forms from the same deposits but of more familiar aspect. The new collection included especially a *Dorsetensia,* and some Stephanoceratids which resembled species from the English Inferior Oolite; and the conclusions of Whitehouse[3] as to the age of the Middle Jurassic deposits of Western Australia seemed confirmed. Yet the re-examination of Crick's types makes me hesitate to accept the general opinion that the ammonites so far described from Western Australia all indicate a single horizon. The localities are widely scattered; there are various types of matrix and preservation; and, knowing how fragmentary are all Jurassic successions even in far more thoroughly explored areas, it seems improbable that the fossiliferous bands in a variable series of deposits such as the Jurassic of Western Australia are of exactly the same age. It will be attempted in the following pages to review the evidence and discuss the relationship of the ammonites so far known from Western Australia.

[1] Die geographishe Verbreitung der Juraformation. *Denkschr. k. Akad. Wiss. Wien*, vol. 50, 1885, p. 140, pl. I., figs. 3-4.

[2] On a Collection of Jurassic Cephalopoda from West Australia, etc. *Geol. Mag.*, Dec. iv., vol. i., 1894, pp. 385-393; 433-441, pls. xii., xiii.

[3] Some Jurassic Fossils from West Australia. *Journ. Roy. Soc. W. Aust.*, vol. xi., 1925, p. 11.

After the MS. had been sent out to Australia, Dr. C. Teichert kindly forwarded some more ammonites from the same beds, including the holotype of *Dorsetensia "etheridgei."* I was thus able to make a few additions; and I was also glad to adopt his suggestions regarding the illustrations now included in this paper. Furthermore, I have to thank him for directing my attention to the two accounts by A. G. Maitland and for communicating the present paper.

II.—THE GROUP OF *STEPHANOCERAS LEICHARTI* NEUMAYR.

The Stephanoeratid ammonites described by Neumayr and Crick (with one exception) belong to a rather well defined group, characterised by cadicone inner whorls that remain first smooth and then striate to a comparatively late stage (up to 25 mm. diameter). Tuberculation appears very gradually, is rather close to the umbilical suture, not at the middle of the whorl-side, and the high and often vertical umbilical slope may be perfectly smooth. It will be noticed that even in the Bathonian *"Stephanoceras* sp. nov." figured by Gemmellaro[1] which has the smooth umbilical slope of the Australian forms, the tubercles are already strong at a small size and about half-way up on the whorl-side.

The secondary ribs meeting in bundles at the umbilical nodes are blunt and projected, even after becoming coarse; the primary ribs are either indistinct, short, or altogether wanting. Neumayr's *Stephanoceras leicharti* well shows the characteristic features of the outer whorls, also the elevated whorl-section. It is therefore now taken as type of the new genus *Pseudotoites,* nov., proposed for the group under discussion.

Dr. Teichert tells me that Neumayr's original publication is not accessible in Western Australia, and, on his suggestion, I am taking the opportunity of reproducing the figures of the holotype of *P. leicharti* Neumayr sp. (see Plate I., fig. 1; Pl. II., fig. 4).

Crick's forms are not easily recognised from the greatly reduced illustrations and they are rather badly preserved and worn; but his *Ammonites (Perisphinctes) championensis* is merely a more delicately ribbed edition of *P. leicharti,* converging towards the perisphinctid genera *Choffatia* or *Indosphinctes,* while *Amm. (Perisphinctes) robiginosus* Crick (with which I include Crick's second example of *Amm. championensis,* B.M., No. C. 4708), is a more robust development in the opposite direction. *Amm. (Sphaeroceras) semiornatus,* Crick, especially the larger paratype, is still more finely ribbed than *Amm. championensis* of which species Crick's *Amm. (Stephanoceras)* sp. is probably a (distorted?) fragment; but *Amm. (Stephanoceras) australis* Crick, though resembling *Normannites,* may represent merely the poorly preserved inner whorls of one of the large forms of the *leicharti-robiginosus* group. Whether Neumayr's *Stephanoceras blagdeni* (*non* Sowerby) and his *Perisphinctes* sp. belong to the group in question is doubtful; Crick's *Amm. (Sphaeroceras?) woodwardi* on the other hand is probably distinct, as will be shown below.

[1] Sopra alcune faune giurese e liasiche della Sicilia V. Sopra alcuni fossili della zona con Posidonomya alpina Gras di Sicilia. *Giorn. Sci. Nat. Econ. Palermo,* vol. xii., 1877, p. 147, pl. xix., fig. 2.

[2] Compare, e.g., *Indosphinctes rusticus,* Spath, Pal. Indica, N.S., vol. ix., No. 2, part 4, 1930, p. 343, pl. lxxx., fis. 7a, b,

In connection with this peculiar *leicharti* group it may be recalled that Chapman[1] recorded an example of *Perisphinctes championensis* with an *aptychus* which was described as rather thin, "a usual character in the *aptychi* known to occur in the Perisphinctidae." The granulate structure of the outer layer was similarly said to correspond with Zittel's group of the *granulosi* "to which the Perisphinctidae seem to belong." This also suggests that the *leicharti* group is distinct from the typical Stephanoceratids, for although very small *aptychi* have been recorded[2] in some doubtful forms, and in various *Stephanoceras*-derivatives, it is improbable that genera like *Otoites* or *Normannites*, with contracted mouthborders and lateral apophyses (at least in the adult), were provided with *aptychi.*

III.—COMPARISON WITH OTHER STEPHANOCERATIDS.

The genus *Otoites* Mascke,[3] to which Whitehouse referred some of the Australian forms, was described as including narrowly-umbilicated ammonites which are globular in the young. *Otoites* is also more or less dwarfed, and excentrumbilicate, with a contracting body-chamber. Comparing the genotype, *O. sauzei* (d'Orbigny)[4] with Neumayr's figure of his *Stephanoceras leicharti,* it will be seen at once that among other differences, the position of the umbilical tubercles is not the same in the two stocks; and the evolute and smooth inner whorls of *Amm. semiornatus* or *Amm. robiginosus*, Crick, do not show much resemblance to a globose young *Otoites.* The Australian group under discussion, in fact, seems to have less affinity with *Otoites* than with many late Stephanoceratid offshoots mentioned by Crick,[5] e.g. *Cadoceras, Erymnoceras, Oleostephanus, Spiticeras, Perisphinctes, Wagnericeras, Obtusicostites,* or even *Polyptychites* and *Rasenia.* Almost the only *Stephanoceratids* of Bajocian age that show features reminiscent of the *leicharti* group are, first the early genus *Docidoceras,* Buckman[6] (*discites* zone) which gave rise both to the typical *Stephanoceras* (*humphriesianum* group) and to *Emileia*; and secondly, *Teloceras warreni* McLearn,[7] at least as regards the tuberculate umbilical edge. The secondary rib-bundles, uniting at the tubercles in this species, are also similar to those of the West Australian forms. Yet the resemblance is superficial; for, apart from the inflation of the Canadian shell, the inner whorls of *T. warreni* are those of a true *Teloceras,* whereas *Zemistephanus,* McLearn, to which genus *T. warreni* is somewhat transitional, has still more exaggerated tuberculation. *Docidoceras* entirely lacks the characteristic smooth and vertical umbilical edge of the Australian ammonites.

The fact that the Canadian Stephanoceratids also show local peculiarities suggests that the Australian *leicharti* group may represent merely a special development, characteristic of a distinct province, and that no time signifi-

[1] On a Collection of Upper Palaeozoic and Mesozoic Fossils from West Australia, etc. *Proc. Roy. Soc. Victoria,* vol. xvi., N.S., pt. 2, 1904.

[2] See Trauth: Aptychenstudien. V. Die Aptychen des Dogger. *Ann. Naturhist. Mus. Wien,* vol. xliv., 1930, pp. 380, etc.

[3] Die Stephanoceras-Verwandten in den Coronatenschichten von Norddeutschland. *Inaug. Dissert.* Göttingen, 1907, p. 25.

[4] Pal. Française, Terr. Jurass., vol. i., 1846, p. 407, pl. cxxxix., figs. 1-3.

[5] Not with the same generic names.

[6] Type Ammonites. Vol. iv., 1922, pl. cccxiv. (*D. perfectum*).

[7] Three Fernie Jurassic Ammonoids. *Trans. Roy. Soc. Canada,* ser. 3, vol. xxvi., sect. 4, 1932, p. 113, pls. iii. and iv.

cance is attached to such horizontal variations. But the Stephanoceratids known from New Guinea[1] or the Malay Archipelago[2] are not strikingly different from European types. I may add that a Stephanoceratid, namely a small *Cadomites*, has now been found by Mr. J. H. Smith in Kachh (bed 26 of Jumara,[3] lowest white limestones with corals and brachiopods) so that the assemblage is acquiring a striking similarity to Lower Bathonian faunas known from Europe, e.g. Sicily. On the other hand, no coronate Bajocian Stephanoceratid of 46 inches diameter, such as a form described by Whitehouse, has ever been found, so far as I know, either in Europe or anywhere else. The largest examples in the British Museum are only a foot or so in diameter, whereas giants are common among the *coronati* of the Callovian (*Erymnoceras*).

IV.—THE ASSOCIATED AMMONITES.

Fortunately, the forms of the curious *leicharti* group are accompanied by other ammonites, e.g. Crick's *Dorsetensia clarkei* and *Amm.* (*Sphaeroceras ?*) *woodwardi*, the types of which are before me. I think Dr. Whitehouse will now agree with me that the former is probably a *Dorsetensia* and not a *Sonninia*, as he thought in 1924; and Crick correctly stated that the genus was common in the *humphriesianum* zone but occurred already in the *sauzei* zone. *Amm. woodwardi*, which I would include in the genus *Normannites*, also indicates the *sauzei* zone; but only if I am right in identifying it with a species of *Normannites*, which is represented in the new collections by two examples in a much better state of preservation than Crick's original. One of these is now figured (Plate II., figs. 3a, b) and it will be seen that the bullate tubercles only appear on the last whorl. *N. woodwardi*, in fact, is only a more involute form of the stock that produced *N.* ("*Epalxites*") *formosus* (S. Buckman)[4] but its earlier whorls are smoother.

The mode of preservation, however, again suggests caution; and association in a condensed deposit does not imply contemporaneity. The *Dorsetensia*, in an orange or brownish limestone, undistorted, and with the suture-line perfectly displayed, may or may not have come out of the same bed as some of the Stephanoceratids, but these are either crushed distorted and worn casts, sometimes entirely limonitic, or else preserved in a red limestone which is distinctly conglomeratic and patchy. These specimens again all look badly worn. The "friable somewhat sandy limestone, yellowish-brown, with purplish patches," in which Neumayr's small suite of fossils was preserved may represent a similar type of rock. It is thus not impossible that the variegated bed which yielded these fossils represents a condensed deposit in which elements of different age became mixed, though there may be little evidence of disturbance in the field.

V.—REVIEW OF THE LOCALITIES.

With regard to the new assemblage, from Mt. Hill, about 30 miles S.E. of Geraldton, I am assured by Dr. C. Teichert, now at the University of Western Australia, that the ammonites must all have come from the same

[1] Gerth: Beiträge zur Palæontologie und Stratigraphie des indischen Archipels. II. *Leidsche geol. Meded.*, Deel ii., Afl. 3, vol. vii., 1927, p. 226.

[2] Wanner: Mesozoicum. *Leidsche geol. Meded.* (Festb. K. Martin), 1931, pp. 584, etc.

[3] See Spath: Revision of the Jurassic Cephalopod Fauna of Kachh (Cutch). *Pal. Indica*, N.S., vol. ix., No. 2, part vi., 1933, p. 760.

[4] Type Ammonites, vol. III., 1920, pl. 551.

horizon. The matrix again is a yellowish to greyish-brown, shelly limestone, with red patches, and rather conglomeratic, but the fossils are not worn. Dr. Teichert's inspection of the fossil locality was rather hurried, but he tells me (*in litt.*) that the two species most frequently found are *Dorsetensia clarkei* and a globular ammonite [Stephanoceratid?], which two forms, moreover, are also rather common around Newmarracarra, east of Geraldton.

The ammonites described by Chapman, Etheridge[1], and Whitehouse also came from the Greenough River district, as did those recorded by Crick as from near Champion Bay. Neumayr's specimens may have come from farther away since he considered the locality "Glenelg River" to be perhaps the Moore River, 60 miles north of Perth. A misreading of Glenelg for Greenough River seemed possible, but Mr. A. Gibb Maitland[2] thinks Neumayr's locality was the Moore River, being adjacent to the area from which Moore's fossils came.

One of Crick's ammonites, it is true, is labelled "Cape Riche, about 50 miles east of Albany"; and this locality, on the south coast of Western Australia, is 500 miles away from the Greenough River. I may add, however, that on H. P. Woodward's[3] geological map no Mesozoic deposits are indicated anywhere south of Perth; and the variegated matrix of the Cape Riche ammonite is identical with that of the Champion Bay specimens.

There must be some error about the locality and, in fact, A. G. Maitland, as long ago as 1907,[4] suggested that Crick's Cape Riche ammonite had been wrongly localised. Though the outcrop of Mesozoic rocks on Woodward's and Maitland's maps extends over some 600 to 650 miles, Glauert's[5] lists suggest that the localities are all on the Greenough River or at least in the neighbourhood of Geraldton (Shark Bay also being doubtful, according to Moore).

VI.—THE NEW MT. HILL ASSEMBLAGE.

The Mount Hill fauna now before me consists of the following cephalopods:—

Dorsetensia clarkei (Crick).
Normannites woodwardi (Crick).
Normannites sp. (cf. *woodwardi* Crick?)
Normannites sp. (cf. *australis* Crick?)
Emileia? sp. nov.?
Emileia? sp. juv. (inner whorls).
Belemnopsis spp. ind.

[1] Oolitic Fossils of the Greenough River District, W. Australia. *Geol. Surv. W. Aust., Bull.* 36, 1910, pp. 38-39.

[2] Geol. Survey W. Aust., Mem. No. 1, (1919), 1920, p. 41.

[3] Geological Sketch Map of Western Australia (1 : 3 000 000), Perth, 1894.

[4] Australas. Assoc. Advanc. Sci., vol. xi., 1907, p. 152

[5] A list of Western Australian Fossils. *Geol. Surv. W. Aust., Bull.* No 36, 1910, p. 105. I cannot find the authority for the inclusion of "*Amm. lautus*" in the list of Jurassic fossils. The ammonite is marked as being in the Geological Society Collection, but the only two ammonites in existence (ard now in the British Museum, Nat. Hist.) are those listed in the Quarterly Journal of the Geological Society (vol. xvii., 1861, p. 483), namely a body-chamber fragment of a form of the *semicrnatus* type, from the Moresby Range (associated with *Trigonia*, and a Gingin Chalk ammonite from the foot of Mt. Albert. The latter is comparable to the Pachydiscids described on a former occasion (Spath, Note on Two Ammonites from the Gingin Chalk, *Journ. Roy. Soc. W. Aust.*, vol. xii., 1926, pp. 53-55).

The first shows an extraordinarily close resemblance, even in suture-line, to *Grammoceras* (*striatulum* group) of the Upper Lias, as previous authors noticed, so that it is chiefly the association with the Stephanoceratids that suggests reference to the genus *Dorsetensia.* There exist, however, sufficiently similar forms of *Dorsetensia,* for example the European *D. deltafalcata* (Quenstedt)[1] or the South American *D. subdeltafalcata,* (Tornquist)[2], to make it probable that this is not a case of persistence of a Toarcian element into the Middle Bajocian, but merely heterochronous homoeomorphy.

The sharply-ribbed Normannites sp. (cf. *woodwardi*) is half-way between *N. depressus* (Whitehouse) and the typical *N. woodwardi,* differing from the latter chiefly in its greater whorl-thickness (60% instead of 45%) and in consequence a steeper umbilical slope. The second species of *Normannites* is a more finely ribbed form and therefore closer to the true *Amm. braikenridgei,* Sowerby[3] than the first. If identical with the badly preserved holotype of *Amm. australis,* Crick, the latter must be removed from the *leicharti* group, i.e. the genus *Pseudotoites.*

The species of *Emileia* (?), doubtfully listed as new, looks like a *Teloceras,* as it rapidly expands; but it has finely ribbed and rather evolute inner whorls, so that it may be compared to one of the examples of *Amm. coronatus,* figured by Quenstedt,[4] or to the (far less inflated) *A. brocchii* (*non* Sowerby), figured by Waagen.[5] There is no contraction, however, at the end of the shell, and since the example is worn, it is not impossible that it is referable to *Teloceras* or perhaps to the un-named large coronate genus mentioned by Whitehouse. A smaller specimen, however, if belonging to the same form, as seems probable, favours the reference to *Emileia.* Another specimen of the same type, received with the second collection is figured in Plate I., figs. 3a, b. It has no tubercles and the inner whorls are almost smooth, but it is too immature for exact comparison.

VII.—THE AGE OF THE FAUNA.

The belemnites, like Crick's *Nautilus perornatus,* are not helpful for exact dating of the assemblage; but the vertical distribution of the Stephanoceratids is now sufficiently well established to justify the reference of this Mt. Hill fauna to the *sauzei* zone. *Emileia* appears (*ex Docidoceras*) in the lower *sowerbyi* zone (*discites* subzone)[6] and persists (in "*Frogdenites*") into the upper *sauzei* zone, but it is gradually being replaced by *Sphaeroceras* s.l. (including *Chondroceras, Labyrinthoceras,* etc.) in this *sauzei* zone, the Sphaeroceratids attaining their maximum in the *humphriesianum* zone but going up into the *parkinsoni* zone.

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[1] See in Haug: Etudes sur les Ammonites des étages moyens du système Jurassique I. *Bull. Soc. géol. France,* ser. 3, vol. xx., 1893, p. 293, pl. ix., fig. 9.

[2] Der Dogger am Espinazito Pass, etc., *Pal. Abhandl.,* N.S., vol. iv., 1898, p. 156, pl xviii., fig. 7.

[3] Refigured in Buckman: Yorkshire Type Ammonites, vol. ii., 1914, pl. lxxxi. (included in *Otoites*).

[4] Ammoniten des schwäbischen Jura., II., 1886, p. 547, pl. lxvii., fig. 6.

[5] Über die Zone des *Ammonites sowerbyi.* *Geogn. Pal. Beitr.* (*Benecke*), vol. i., 1868, p. 601, pl. xxiv., figs. 3a, b.

[6] See Spath: Bajocian Ammonites and Belemnites from Eastern Persia (Iran). *Pal. Indica,* N.S., vol. xxii., No. 3, 1936, p. 16.

Stephanoceras itself, also derived from the stock that produced the early *Docidoceras,* with its various offshoots, like the extremely evolute *Skirroceras* or the dwarfed *Phaulostephanus,* ranges through all the subzones of the *sowerbyi, sauzei* and *humhriesianum* zones, while its final development, *Cadomites,* persists into the Bathonian. *Otoites* is not definitely known in the lower (*discites*) and middle (*trigonalis*) subzones of the *sowerbyi* zone, unless *Trilobiticeras,* Buckman, is an early form of *Otoites;* but it occurs in the upper division (*laeviuscula* subzone), and is dominant in the lower and upper *sauzei* zone, where it is being gradually replaced by *Normannites.* First *Stemmatoceras* and then *Teloceras* are the typical elements of the lower (*romani* subzone) and upper *humphriesianum* zone (*blagdeni* subzone).

Now, while it is not difficult to place in this time-scale (assuming the vertical distribution to hold universally) the well-preserved *Normannites woodwardi, N. deprsessus,* etc., whichever genus they are referred to, there is no guidance for dating the badly preserved and worn forms of *Pseudotoites,* i.e., the *leicharti* group. For, if they are derived, they would have to be even earlier than the *sauzei* zone, and not later, as might be thought probable from their morphological characters. We are thus driven to the conclusion that *Pseudotoites* represents a local, Australian genus of Stephanoceratids, existing during *sauzei* or perhaps *sowerbyi* times, which has no counterpart elsewhere, yet shows features characteristic of various late *Stephanoceras* derivatives.

It is highly desirable, however, to investigate more critically the conditions of deposition of the ammonite bearing bed or beds, and to collect more favourably preserved examples of the species of *Pseudotoites* above discussed, noting their association with fossils that cannot have been derived. Of course, if Cricks' Champion Bay specimens should have been collected from the bed of the Greenough River, as seems possible,[1] their worn condition is readily explained.

VIII.—NOTE ON *DORSETENSIA CLARKEI,* CRICK.

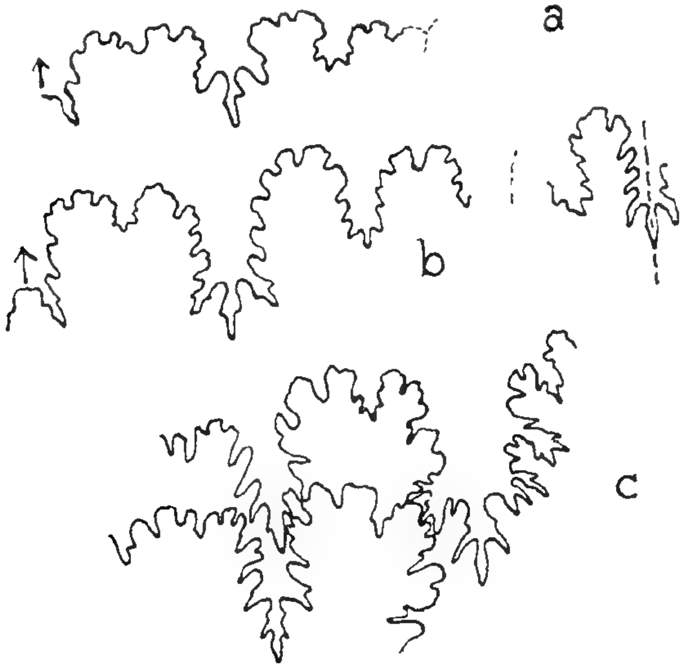
Having sent me the holotype of *D. etheridgei,* Whitehouse (because it had never been described in detail), Dr. Teichert suggested that I add a note on the results of my re-study of that form as well as on its relations to *D. clarkei,* Crick. I gladly adopt this suggestion and hope that at any rate the figures will prove useful to geologists in West Australia.

Crick's greatly reduced figure made it difficult to recognise *D. clarkei,* but there is not a single feature on which separation of the two species could be based. Etheridge had not misinterpreted *D. clarkei,* as Whitehouse thought; for both his Tibraddon specimen (pl. ix., fig. 7) and the Snake Farm example (pl. vi., fig. 4) show almost perfect agreement with Crick's type, even in the mode of preservation. In addition to these three figured specimens I have now before me two more typical examples from Mt. Hill, also the inner whorls and the large fragment figured in Plate I., fig. 2 and Plate II., figs. 2a, b. There are slight differences in the suture-lines (Text-fig. 1a, b), and in the width of the periphery, or in the more or less gradual disappearance of the two grooves accompanying the keel as the shell in-

[1] See F. T. Gregory: On the Geology of Part of Western Australia. *Quart. Journ. Geol. Soc.,* vol. xvii., 1861, p. 480.

creased in size. But these differences are not sufficient to make even varieties and I am therefore including all these seven examples in the one species *D. clarkei*, Crick.

Since the original figure was reduced and the suture-line somewhat too diagrammatic (with the outer half of the external saddle corroded) I am refiguring Crick's holotype (Plate II., figs. 1a, b) and it will be seen that it is indistinguishable from a portion of Etheridge's larger specimen (pl. ix., fig. 7), comprising the left-hand portion, from the last break but one, to about a quarter of a whorl from the end (Etheridge's figure is reduced x 4/5). The only difference I can see is that the lobes are more dependent towards the umbilical suture than in the type.



Text-fig. 1.—Suture-lines of (a) *Dorsetensia clarkei*, Crick, small specimen figured in Plate II., fig. 2, enlarged x 4; (b) larger fragment, represented in Plate I., fig. 2 (with umbilical edge damaged), enlarged x 2; (c) part of suture-line of very large example of *Dorsetensia* (?) sp. ind. discussed below.

In Etheridge's smaller specimen (pl. vi., fig. 4), the second lateral and auxiliary lobes again are as ascending inwards as in the suture-lines here figured; but this second specimen is slightly more compressed than Crick's type, also a difference of no consequence, especially since the preservation of both of Etheridge's examples is imperfect.

A large eighth specimen of a *Dorsetensia* (No. 800, from near Newmarracarra) is of interest because it combines the characteristic periphery of *D. clarkei*, i.e., a blunt and low median keel and faint lateral grooves, with a small umbilicus (about 23%). The specimen is of approximately 230 mm. diameter, separate to about 160 mm. and portions of the last few suture-lines are given in Text-fig. 1c to show that they are not strikingly different from those of smaller specimens. The ribbing is completely lost on the outer whorl, but since the septate part of the specimen is hollow and an attempt to uncover the inner whorls would only result in more or less complete destruction of the ammonite, it is impossible to compare them with the examples of *D. clarkei* above discussed. I can only say that if this large

example belongs to Crick's species, then the contraction of the umbilicus from 46% to 23% is rather remarkable. Judging from the aspect of the outer whorl alone, however, the specimen might also be a *Witchellia*, for forms like *W. falcata*, S. Buckman,[1] at the diameter of the Australian specimen, are smooth and very similar, even in suture-line.

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[1] Type Ammonites, vol. VI., 1926, pl. 688.

EXPLANATION OF PLATES.

Plate I.

Fig. 1.—*Pseudotoites leicharti* (Neumayr). "Glenelg" (= Moore) River. Copy of fig. 4a of Neumayr's plate. (For peripheral view see Plate II., fig. 4.) Original in the Geological Institute of the University of Vienna.

Fig. 2.—*Dorsetensia clarkei*, Crick. Part of a fragmentary example from 19m. cutting, near Newmarracarra. (For suture-line see Text-fig. 1b.) (Univ. W. Aust. Coll.)

Fig. 3.—*Emileia* (?) sp. juv. Showing smooth inner whorls. Mt. Hill. (Same Coll.)

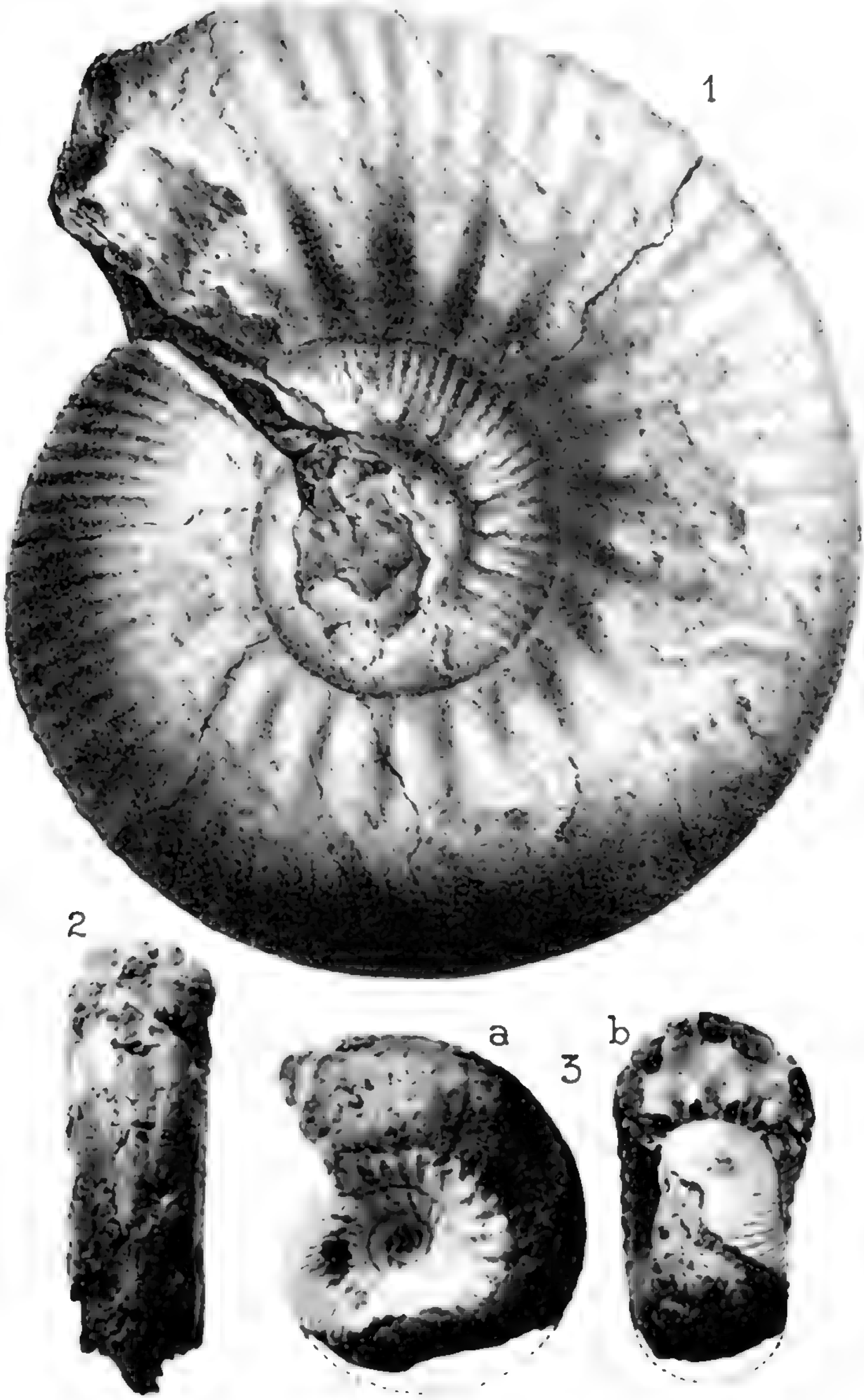

PLATE I.

Plate II.

Fig. 1.—*Dorsetensia clarkei*, Crick. Holotype. Champion Bay. (British Mus. [Nat. Hist.], No. C30376.)

Fig. 2.—*Dorsetensia clarkei*, Crick. Inner whorls. Fossil Hill, near Newmarracarra. (Univ. W. Aust. Coll., No. 5146.) Compare sharp keel with blunt carina of Plate I., fig. 2 (both casts).

Fig. 3.—*Normannites woodwardi* (Crick). Example from Mt. Hill, believed to be same species as badly-preserved holotype from Champion Bay. (Univ. W. Aust. Coll.) Complete, with mouth-border partly preserved; last suture-line at x.

Fig. 4.—*Pseudotoites leicharti* (Neumayr). Peripheral view of the ammonite figured in Plate I., fig. 1. (Copy from Neumayr.)

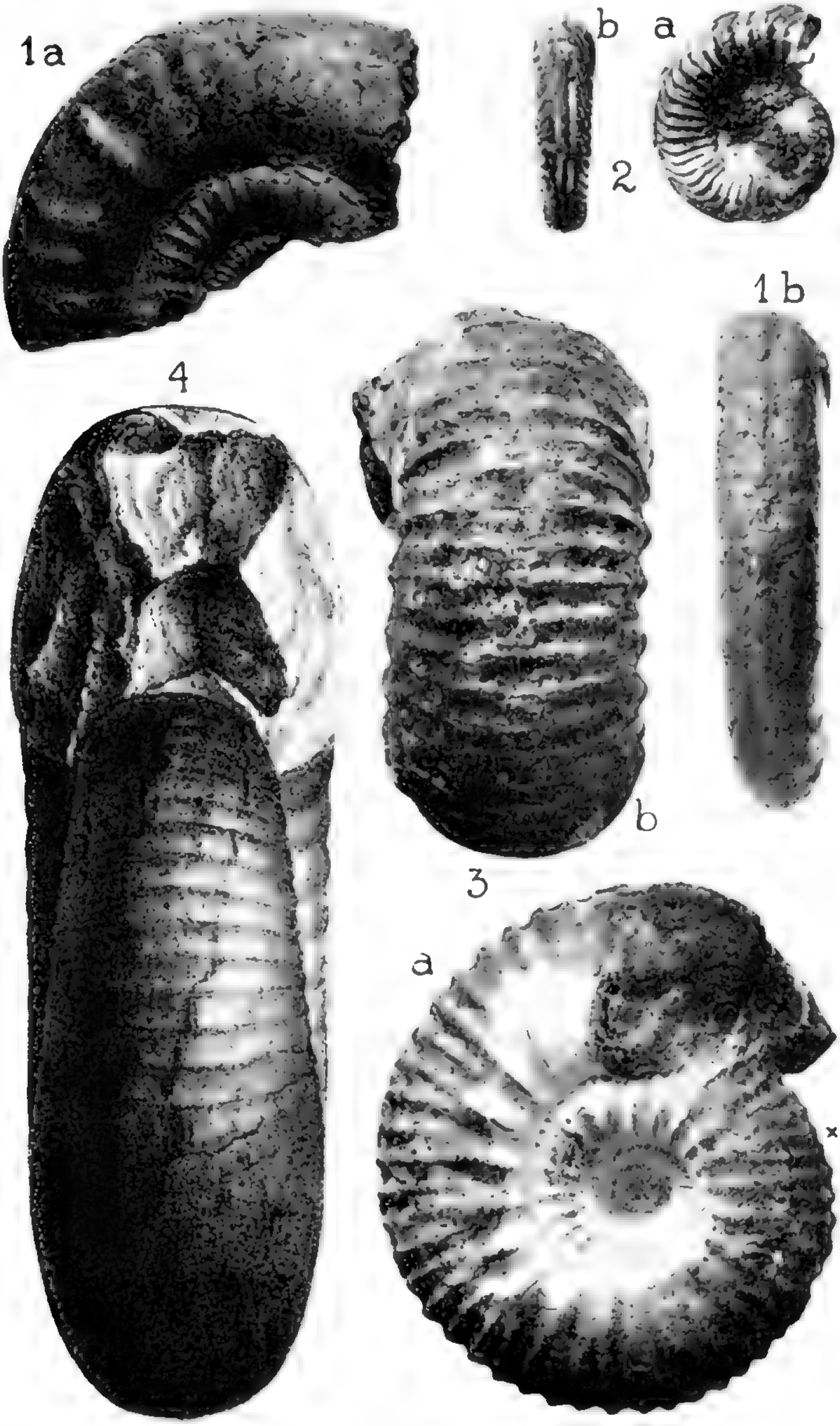

PLATE II.

7.—CARMINITE AND BINDHEIMITE FROM THE ASHBURTON DISTRICT.

BY

C. R. LE MESURIER.

Read 18th April, 1939; Published 25th August, 1939.

CARMINITE, HARDEY RIVER.

Carminite, a hydrous arsenate of lead and iron, was first reported by Sandberger, who found it associated with beudantite and quartz in limonite from Horhausen on the Rhine. He named it Karminspat from the red colour, but later Dana adopted the name Carminite. Carminite has also been reported from Cornwall, Utah, Colorado, and from the Magnet Silver mine in Tasmania, but this last occurrence is held by Anderson (1) to be actually Crocoite. The rather complex formula, $Pb_3As_2O_8 \cdot 10FeAsO_4$, suggested by Dana, Doelter and others, is necessarily tentative, as it is based on one analysis made on ·07 gm. of material; further it does not indicate any combined water.

In 1937, W. F. Foshag (2) published an analysis of carminite from Mapimi, Mexico, where it occurs associated with scorodite, dussertite, arseniosiderite, mimetite, cerussite, anglesite and plumbojarosite. He was able to obtain sufficient reasonably pure material for an accurate analysis, and simplified the formula to $PbO \cdot Fe_2O_3 \cdot As_2O_5 \cdot H_2O$.

The West Australian mineral which forms the subject of this paper was received at the Government Laboratory at the end of 1937 from a locality given as near the Log Hut on Wyloo Station, 30 miles E.S.E. of Mt. McGrath, and two miles south of the Hardey River in Lat. 22°55″ S., Long. 116°35″ E.

In the hand specimen the mineral in considerable masses has a scoriaceous appearance and brick red colour; it also occurs as incrustations in vughs. It is associated with scorodite, anglesite, galena, quartz and possibly beudantite. Under the microscope it is translucent, and is red to amber in colour; it is usually massive, but prism shaped crystals were observed. These are often in sheaf-like forms and are rarely more than ·1 x ·03 mm., with acute termination and straight extinction. The lowest refractive index is higher than that of methylene iodide (1·74) and the birefringence is moderate. Pleochroism is not marked.

The specific gravity of the mineral analysed was 5·22. H.5. An analysis of the purest mineral obtainable after eliminating 0·62 per cent. quartz is given below, with that of the Mapimi material for comparison.

(1) Records of the Australian Museum, 1906, pp. 133–144. (2) The American Mineralogist, Vol. 22, No. 5., 1937, p. 479.

ANALYSES OF CARMINITE.

	Hardey River.		Mapimi.	
	%	Mols.	%	Mols.
PbO	38·14	1,707	37·30	1,675
Fe_2O_3	23·07	1,445	23·43	1,467
FeO	tr.	...	·21	29
As_2O_5	33·22	1,446	33·98	1,426
P_2O_5	·30	21	n.d.	...
H_2O	3·71	2,061	2·90	1,687
H_2O	*	...	·10	..
SO_3	1·35	168	n.d.	..
CaO	*nil*	...	·44	78
MgO	*nil*	...	·06	15
Al_2O_3	n.d.	...	·96	94
Insol.	...	..	·58	
Total ...	99·80	...	99·96	...

* Analysis made on mineral dried at 100 C.

Assuming that the P_2O_5 replaces As_2O_5 in the molecule, and that the SO_3 is combined with PbO in the form of anglesite, the result comes very close to the simple formula put forward by Foshag, with the exception that the water is somewhat higher, $1\frac{1}{2}$ molecules as against one molecule.

SUMMARY AND CONCLUSIONS.

A description and chemical analysis is given of the mineral carminite from the Ashburton District.

The formula deduced corresponds very closely with that given by W. F. Foshag to the Mapimi mineral and may reasonably be adopted.

This appears to be the first authenticated occurrence of carminite in Australia.

BINDHEIMITE MT. AMY AND GORGE CREEK.

This hydrated antimonate of lead is found associated with silver lead ores in many parts of the world, occurring in Australia in the Barrier Ranges of New South Wales, and in Tasmania, but has not previously been reported from Western Australia.

In 1937 specimens of the mineral were received at the Government Laboratory from two localities in the Ashburton District, (1) from Colvin's lead show at Gorge Creek in Lat. 23°15″ S. and Long. 116°40″ E., 12 miles S.E. of Mt. Dawson (also called Mt. Mortimer); (2) from P.A. 150 in Lat. 22°16″ S. and Long. 115°52″ E., $3\frac{1}{2}$ miles S.E. of Mt. Amy, about 80 miles in a north-westerly direction from Mt. Dawson.

In both cases the mineral occurs as a filling of cavities in a granular mass of cerussite, anglesite and quartz and is contaminated with kaolin, limonite and alunite. In the hand specimen the appearance is earthy, and the colour corresponds to Ridgways 19′C between Naples yellow and mustard yellow.

Under the microscope it is opaque and amorphous, with a refractive index higher than that of methylene iodide. In the closed tube water is given off, and the mineral blackens but is infusible at full heat of the bunsen.

Results of analyses of the West Australian mineral are shown below, together with analyses of bindheimite from Nevada, Idaho and Bosnia for comparison.

The mineral from Gorge Creek was first treated with 2E·HNO_3 and ammonium acetate to remove cerussite and anglesite, there being insufficient mineral for a complete analysis to be made.

ANALYSIS OF BINDHEIMITE.

	1. Gorge Creek.		2. Mt. Amy.		3. Secret Canon, Nevada, Hillebrande.		4. Idaho, E. V. Shannon.		5. Bosnia Tscherne.	
	%	Mols to Bindheimite.	%	Mols to Bindheimite.	%	Mols to Bindheimite.	%	Mols to Bindheimite.	%	Mols to Bindheimite.
Sb_2O_5 ...	38·57	119	16·13	50	35·20	109	53·48	165	37·48	116
PbO ...	32·12	144	59·05	111	49·50	164	36·54	150	50·12	225
H_2O+	3·98	100	3·21	93	5·86	320	3·27	164	7·39	375
H_2O-	1·43		·42				·30			
Fe_2O_3	4·43	...	2·32	...	·09	...	3·84	...	5·60	...
Al_2O_3 ...	7·37	...	4·48	...	...	...	...	...	...	...
MgO ...	*nil*	...	*nil*	...	·03	...	...	...	...	...
CaO ...	*nil*	...	*nil*	...	·66	...	...	...	...	...
Na_2O ...	...	...	·60	...	·21	...	...	...	...	...
K_2O ...	...	...	·26	...	·14	...	...	...	...	...
CO_2 ...	...	...	7·06	...	3·35	...	·60	...	...	...
SO_3 ...	...	...	3·66	...	...	...	...	...	...	...
P_2O_5 ...	*nil*	...	tr.	...	...	...	...	...	...	...
CuO ...	*nil*	...	1·05	...	·58	...	...	...	...	...
ZnO ...	...	...	...	...	·18	...	...	...	...	...
Ag ...	...	...	...	...	·29	...	...	...	...	...
SiO_2 ...	6·07	...	1·30	...	4·59	...	2·28	...	...	...
Total	93·97	...	99·54	...	100·68	...	100·31	...	100·59	...
Formula	...	...	$2PbO \cdot Sb_2O_5 \cdot H_2O$ Lead orthoantimonate		$3PbO \cdot 2Sb_2O_5 \cdot 6H_2O$ Pb orthoantimonate + Pb metantimonate		$PbO \cdot Sb_2O_5 \cdot H_2O$ Pb metantimonate		$2PbO \cdot Sb_2O_5 \cdot 3H_2O$ Pb orthoantimonate	

It will be seen that the ratios of lead, antimony and water vary considerably, but with the exception of 1 (Gorge Creek) correspond to the meta—or ortho—antimonates, or a mixture of these, with varying amounts of water.

On the other hand, many of the published analyses do not conform to any simple formula, and are probably contaminated with antimony ochre, which on account of its stability is a common oxidation product of antimony ores and is practically impossible to separate from a mineral such as bindheimite.

CONCLUSION.

It would seem that it is impossible to assign a definite formula to bindheimite as careful analyses show evidence of both the ortho and meta forms due, no doubt, to the conditions under which the mineral is formed.

8.—WESTERN AUSTRALIAN DEVONIAN CORALS IN THE WADE COLLECTION.

BY

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(Communicated by Dr. C. Teichert.)

Read 14th March, 1939; Published 2nd November, 1939.

In this paper four further species from the Rough Range Series (Upper Givetian or Lower Frasnian) of the Kimberley District of Western Australia are described, and reviews are given of the Families Syringaxonidae and Metriophyllidae.

These corals were collected by Dr. A. Wade (1938, p. 96), and are now in the University of Western Australia. The table shows the localities; the species illustrated herein are listed in heavy type, and other entries give new localities for species previously described (Hill, 1936). The fauna indicates either an Upper Givetian or a Lower Frasnian horizon, and the presence of *Alveolites* with *Thamnopora* and the apparent absence of *Favosites* and *Heliolites* make the higher horizon seem more likely.

	A408	A581	B92	B94
Alveolites suborbicularis Lam.				x
Barrandeophyllum rubrum sp. nov.	x	x		
Disphyllum virgatum (Hinde)*				x
D. depressum (Hinde)			x	
Metriophyllum sp.	x			
Prismatophyllum brevilamellatum Hill				
Thamnopora cf. *dubia* (de Blain)			x	

Table of Occurrences.

A408. South-eastern entrance of Mountain Home Spring Valley, Rough Range, Kimberley District.

A581. Napier Range, Kimberley District.

B92. Trigonometrical Station J, Rough Range, Kimberley District.

B94. 10 chains East of Trigonometrical Station K, Rough Range, Kimberley District.

B92 and B94 are in the massive grey limestones of the Rough Range, A408 and A581 are in red limestone below the massive grey and are thought by Dr. Wade to be near the base of the Rough Range Series.

RUGOSE CORALS.

Family SYRINGAXONIDAE.

Type Genus: **SYRINGAXON** Lindström, 1882, p. 20.

Diagnosis: Simple Rugose corals with the axial ends of the major septa united at the tabulate aulos, with inclined tabellae between the aulos and the outer wall; with contratingent minor septa and without dissepiments.

Range: Silurian to Permian.

Remarks: The genera here included in the family are (1) the Silurian *Syringaxon* of Europe, recently studied by Butler (1935), (2) the Silurian *Laccophyllum* Simpson of America; (3) the Silurian and Devonian *Alleynia*

*Mlle. Le Maitre (1937, p. 107) has described this species from the Givetian of France, and also referred to it a form from the Upper Devonian of India, called *Cyathophyllum* (*Thamnophyllum* sp) by Cowper Reed.

(*Nicholsonia*) Pocta (1902, p. 184) of Bohemia, these three genera probably being synonyms, as all are distinguished by dilatation ; (4) the Lower Devonian *Retiophyllum* Pocta (1902, p. 180) of Bohemia and (5) the Middle Devonian *Barrandeophyllum* Pocta of Bohemia, with which *Retiophyllum* is probably synonymous ; (6) *Diphyphyllum symmetricum* Frech (1886, p. 95) from the Lower Givetian of Germany, which, however, has no minor septa ; (7) the Russian Upper Devonian *Laccophyllum* of Gorsky (1932, p. 8) ; (8) the German Lower Carboniferous *Diphyphyllum irregulare* of Kunth (1869, pl. ii, fig. 5) ; (9) possibly the Russian Lower Carboniferous *Permia* Stuckenberg (1895, p. 186), although some of the figures suggest the presence of dissepiments and a possible affinity with *Aulophyllum* Edwards and Haime ; and finally (10) the Russian Lower Permian *Amplexocarina* Sochkina (1928), in which minor septa may or may not be developed. Of these, *Laccophyllum, Alleynia, Barrandeophyllum* and *Permia* constituted Grabau's (1928, p. 82) family Laccophyllidae ; as *Laccophyllum* is in all probability synonymous with *Syringaxon*, I have given the earlier name of the genus to the family.

The Silurian and some of the Devonian forms have dilated tissue, but in the later Devonian and Carboniferous forms the plates are usually moderately thin. Many other forms with a tabulate aulos have a dissepimentarium, *e.g.*, the Devonian *Eridophyllum* and the Carboniferous *Aulina*, and the possibility that these have arisen from the Laccophyllidae should be kept in mind.

Genus **BARRANDEOPHYLLUM** Pocta.

Barrandeophyllum Pocta, 1902, p. 190.

? *Retiophyllum* Pocta, 1902, p. 180 ; monotype, *Retiophyllum mirum* Pocta *id.*, pl. 108, fig. 6 ; F_2 (Lower Devonian) Koneprus, Bohemia.

Genotype (by monotypy) : *Barrandeophyllum perplexum* Pocta, 1902, p. 192, text-figs. 9, 10, pl. 108, figs. 4, 5, 7, 13, 19 ; G_1 (Couvinian), Hluboçep, Bohemia.

Diagnosis : Simple Rugose corals with the axial ends of the major septa uniting at a tabulate aulos ; with inclined tabulae between the aulos and the outer wall ; typically with contratingent minor septa ; with unthickened tissue.

Remarks : Pocta was uncertain of the arrangement of the axial ends of the septa in *Retiophyllum*, but from his figure, the genotype seems to be *Barrandeophyllum. B. perplexum* has contratingent minor septa ; but I am here including in the genus two species which appear to be without minor septa. These are the German Lower Givetian *Diphyphyllum symmetricum* Frech and a smaller form from the Rough Range Series of Western Australia.

Barrandeophyllum rubrum sp. nov.

(Plate I., figs. 1 and 2.)

Diphyphyllum sp. cf. *symmetricum* Frech ; Wade, 1938, p. 96, from preliminary determination by Hill.

Holotype : A 408a, Wade Collection, University of Western Australia. Rough Range Series, south-eastern entrance of Mountain Home Spring Valley, Kimberley District, Western Australia. Upper Givetian or Lower Frasnian.

Diagnosis : Barrandeophyllum without minor septa, and with 18 major septa at a diameter of 6 mm.

Description : The corallum is nearly erect or curved, attaining a diameter of 8 mm. at the edge of the calice, which is there 4 mm. deep. Height is probably about 15 mm. The epitheca shows fine growth annulation and very

weak longitudinal ridges. There are 18 thin major septa at a diameter of 6 mm., each proceeding about half-way to the axis, where it meets a thin aulos, which is not always continuous, but is about half the diameter of the corallum. In the holotype one septum, possibly the counter, is slightly swollen at its axial end, but this was not observed in other specimens. The major septa are almost straight, and there are no minor septa. The tabulae in the aulos are complete, horizontal and distant, but irregularly spaced ; those between the aulos and the outer wall are complete or incomplete, usually inclined from the aulos down to the outer wall ; they do not correspond in position or number with the tabulae inside the aulos.

Remarks : The tissue in topotypes is uniformly thin ; but in specimens from A 581, Napier Range, it is somewhat dilated. Also, these latter individuals are smaller and have fewer septa than the topotypes. The species is very close to *Barrandeophyllum symmetricum* (Frech, 1886, p. 95, pl. vii, figs. 3, 4, 5, 17–22) from the Lower Givetian Crinoid bed of Blankenheim, Germany, the only observable differences being those of size of corallum and number of septa.

Family **METRIOPHYLLIDAE.**

Type Genus : **METRIOPHYLLUM** Edwards and Haime.

Diagnosis : Rugose corals without dissepiments, in which all the major septa unite at the axis, the cardinal fossula is on the convex side of the corallum, and a false counter fossula appears ; the minor septa are short and the tabulae are distant and steeply domed ; the axial end of the counter septum may be swollen.

Range : Upper Couvinian to Permian.

Remarks : The genera here regarded as forming a family were previously discussed (Hill, 1938, p. 25) merely as a morphological group of Zaphrentoid corals. Although the group may be a polyphyletic one, this has not been proved, and convenience of reference is now served by regarding it as a family. Genera are the Middle Devonian *Stereolasma* Simpson (1900, p. 205) and *Lopholasma* Simpson (1900, p. 206) of America, and the Middle and Upper Devonian *Metriophyllum* of Europe and Australia ; the European Lower Carboniferous *Zaphrentis omaliusi* group described by Carruthers (1908, p. 25) which may be the Russian Lower Carboniferous *Disophyllum* Tolmatchoff (1931, p. 341) and the Scottish Lower Carboniferous *Fasciculophyllum* Thomson (1883, p. 448) ; the Moscovian "Densiphylloid *Zaphrentis*" (Dobrolyubova, 1936, p. 101, fig. 27) from Russia ; the Uralian *Lopholasma* and *Lophocarinophyllum* Grabau (1922, 1928, p. 147) from China ; and the Permian *Lopholasma* (Soschkina, 1928) from Russia and *Malonophyllum* Okulitch and Albritton (1937) from Texas, U.S.A.

Fasciculophyllum and *Malonophyllum* are distinguished by the swollen axial end of the long counter septum ; and this suggests that other genera with such a feature may bear some relation to the Metriophyllidae. Such are the Lower Carboniferous *Lophophyllum* Edwards and Haime (1850, p. lxvi) ; the Uralian and Permian *Sinophyllum* Grabau (1928, p. 99) ; the Pennsylvanian and Permian *Lophophyllidium* Grabau (1928, p. 98) ; and the Permian *Timorphyllum* Gerth (1921, p. 69) and *Sochkineophyllum* Grabau (1928, p. 75).

Grabau (1928) has discussed most of the genera mentioned above and has given a different interpretation of family relations.

Genus **METRIOPHYLLUM** Edwards and Haime.

Metriophyllum Edwards and Haime, 1850, p. lxix.

Lopholasma Simpson, 1900, p. 206, figs. 19–21; genotype *Streptelasma rectum* Hall, 1876, pl. 19 *partim*, *i.e.*, that called *Lopholasma carinatum* by Simpson *id.* Hamilton shales (Givetian) Western New York.

Genotype (by designation): *Metriophyllum Bouchardi* Edwards and Haime, *id.*, 1851, p. 318, pl. vii., figs. 1, 1a, b, 2, 2a = *Cyathomitratum* Michelin, 1845, p. 183, pl. xlvii., fig. 7, *non* Schlotheim, 1820. Frasnian, Ferques, near Boulogne, France.

Diagnosis: Simple Rugosa without dissepiments, in which the major septa unite at the axis, forming a false columella; the cardinal fossula is on the convex side of the corallum and a false counter fossula appears; the tabulae are incomplete, thin and distant, arranged in tall domes; the septa bear horizontal flanges usually with upturned edges.

Range: Upper Couvinian of Germany, Givetian of Germany and America, and Frasnian of France.

Remarks: Lopholasma is indistinguishable from *Metriophyllum.* The horizontal flanges on the sides of the septa are very prominent and in vertical section of the corallum simulate tabulae. *M. gracil* Schlüter (1884; 1889, pl. ii, figs. 5–8) from the Upper Couvinian of Gerolstein in the Eifel, is a small species 4 to 10 mm. tall and 3 to 4 mm. in diameter, with strongly ridged epitheca, and straight major septa. This form characterises the marl banks; in a dolomitic bed of the same horizon a number of specimens with a smooth epitheca and nearly twice as large are found, which Schlüter (1889, p. 20) suggested might be called *M. laeve*, if these differences should prove real and not a matter of preservation. *M. carinatum* (Simpson) from the ? Givetian (Hamilton) of Western New York, may be 40 mm. tall and 20 mm. in diameter, and its septa are crowded, up to 32 of each order, the minor being short and often contratingent. *M. bouchardi* from the Frasnian of Ferques, France, is two or three times as tall and thick as *gracile*, but has 22 to 24 septa, slightly curved. *M. battersbyi* Edwards and Haime (1853, p. 222, pl. xlix, fig. 4) from Torquay has dissepiments and is probably not *Metriophyllum*.

METRIOPHYLLUM sp.

(Plate I, fig. 3.)

Metriophyllum sp. cf. *gracile* Schlüter; Wade, 1938, p. 96, from preliminary determination by Hill.

Description: The single slightly oblique section of this form here figured was obtained from a piece of red limestone from locality A 408, South-Eastern entrance to Mountain Home Spring Valley, Rough Range, associated with *Barrandeophyllum rubrum*. No other section was possible, and no details can be given of external form, size, or longitudinal section. At a diameter of 9 mm. there are 20 major septa alternating with 20 minor septa, all being a little thickened; the major septa proceed almost to the axis, and are then in contact laterally, leaving an axial space, which is, however, occupied by stereoplasm, possible deposited on the surface of a tabula. Each minor septa is about 1 mm. long, and leans on the major septa on its counter side (*i.e.*, it is contratingent), except for those on either side of the counter septum, which have free edges. The cut edges of the horizontal septal carinae appear as thin offset plates from the major septa. The curvature of the thin sections of tabulae indicate that these are distant and steeply domed.

Remarks : The species differs from the Upper Couvinian (and possibly Lower Givetian) *gracile*, to which it was at first compared in being much larger and in having minor septa. From the Givetian *carinatum* it differs in having fewer septa ; from the Frasnian genotype it is apparently not very different, but as I have neither sections nor good figures of *bouchardi* I cannot be sure. Having such limited material, I have not thought it advisable to give the form a name. On the whole it would appear to indicate a Givetian or a Frasnian horizon.

TABULATE CORALS.

Genus **ALVEOLITES** Lamarck.

Alveolites Lamarck, 1801, p. 375.

Genotype : *Alveolites suborbicularis* Lamarck, 1801, p. 376, Frasnian, Germany.

Range : Silurian and Devonian.

Remarks : The genus has already been discussed in this Journal (Hill, 1936, p. 33, *quo vide*).

Alveolites suborbicularis Lamarck.

(Plate I., fig. 4.)

Alveolites suborbicularis Lamarck, 1801, p. 376. Upper Devonian (Frasnian), near Düsseldorf, Germany.

Alveolites suborbicularis Lecompte, 1933, pp. 15–25 ; 1936, p. 6.

Neotype (chosen by Smith, 1933, p. 138) *:* One of the syntypes of *Calamopora spongites* var. *tuberosa* Goldfuss, 1828, pl. xxviii., figs. 1a–g ; Upper Devonian of Bensberg, near Cologne, in the Goldfuss Collection, Bonn University, *i.e.*, specimen figured *loc. cit.* 1a–1b.

Diagnosis : *Alveolites* whose corallites have thick or thin walls, and are semi-lunar or sub-triangular in section ; a row of coarse spines may be present on the floor of the corallites, or a number of sporadically distributed small spines.

Description of West Australian specimen B 94a: The specimen is a yellowish fragment 8 cm. x 5 cm. x 2 cm., worn by rain weathering. Grouped layers of corallites due to repeated rejuvenescence of the colony are prominent. The corallites are almost completely reclined, in somewhat undulating layers. They are sub-triangular or semi-lunar in transverse section, and are from 0·75 mm. to 1 mm. along their longest horizontal diameter, and from 0·4 to 0·75 mm. tall. A large septal spine is occasionally visible in the centre of the floor of a corallite ; smaller spines are not observed. Pores occur uniserially on the short sides of the corallites, usually at the lower angles ; they are about 0·15 mm. in diameter, and a weathered surface shows 9 in a space of 10 mm. The walls of the corallites are fairly thick over most of the sections taken, about 0·5 mm., but those of the basal layer of corallites after a rejuvenescence are much thinner. The tabulae are very thin plates transverse to the length of the corallites, very slightly sagging, about 1 mm. apart.

Remarks : Lecompte (1933) has given an excellent account of the synonymy, morphology, development and range of this species. It is widespread in the Frasnian of Belgium and France, particularly in the stage of *Rhynchonella cuboides.* In Germany and England it occurs in the Givetian and Frasnian ; in the Carnic Alps it is reported from the Couvinian and Givetian ; in America it is widely distributed. This is the first record in Australia ; the specimen is from B 94, 10 chains East of Station K, Rough Range. In the Australian form the tabulae are much more widely spaced than in the types—5 or 6 as against 12 in 5 mm.

Genus **THAMNOPORA** Steininger.

Thamnopora Steininger, 1831, p. 10; 1834, p. 334.

Genotype : *Alveolites cervicornis* de Blainville, 1830, p. 370. Middle Devonian, Eifel.

Range : Silurian, Devonian and Permian.

Remarks : The genus has already been discussed in this Journal (Hill, 1937, p. 56, *quo vide* for references, etc.).

THAMNOPORA DUBIA (de Blainville)*.

Alveolites dubia de Blainville, 1830, p. 370 (= *Calamopora polymorpha* Goldfuss, 1826, p. 75, pl. 27, fig. 5).

Favosites dubius Lecompte, 1936, p. 54, *quo vide* for discussion of synonymy.

Holotype : The specimen in the Goldfuss Collection, Bonn University, figures by Goldfuss *loc. cit.* from Bensberg, near Cologne, Germany. Frasnian.

Diagnosis : *Thamnopora* with bi- or tri-furcating cylindrical slightly flexuous branches 4 to 6 mm. across; with corallites from 1·5 to 2 mm. in diameter, opening at about 60° from the horizontal, the thickening of the walls increasing distally.

THAMNOPORA cf. **DUBIA** (de Blainville).

(Plate I., fig. 5.)

Thamnopora polyporatus (*sic*) Wade, 1938, p. 96, from preliminary determination by Hill. Rough Range Series, Kimberley, W. Aust.

Description : The specimens are in a red earthy limestone, and the corals are broken by small faults of very slight displacement. The branches vary in diameter between 12 mm. and 7 mm.; perhaps they are somewhat flattened, but this could not be clearly ascertained. They are slightly flexuous, and probably dichotomous. The calices are polyfonal, the openings about 1 mm. in diameter; the common wall between two such calical openings is about 1 mm. thick, and has a median groove corresponding to the median dark line seen in thin sections of the wall. The corallites diverge from the axis with a fairly regular curve, the obliquity being about 40° from the horizontal at the opening. In the axial portion of the transverse section, which is about half the diameter of the branch, the corallites vary in diameter between 0·5 and 0·75 mm., the common walls being about 0·15 mm. thick. At their openings the corallites are about 2 mm. in diameter from dark line to dark line, the common walls being about 1 mm. thick. The increase in thickness of the wall is gradual from the axis to the calice. Mural pores are about 0·2 mm. in diameter and about 0·6 mm. apart. Septal spines were not observed. The tabulae are fine, distant, and slightly sagging. The fibro-radiate structure of the walls and the growth lamellation at right angles to it are clearly seen.

Remarks : This West Australian specimen from B 92, Trig. Station J, Rough Range, differs from the types in that the branches are somewhat thicker, the obliquity of the corallites is less, as they open at 40° as against 60° from the horizontal, and in the slightly greater thickness attained by the walls at the calices. In these characters it resembles closely "*Favosites dubia*" of Milne Edwards and Haime, from an unknown locality, figured by Lecompte (1936, pl. x., fig. 2), but unlike this latter has no septal spines. De Blain-

*Unpublished work by Dr. Stanley Smith and Dr. W. D. Lang indicates that this species is a synonym of *Thamnopora polyforatus* (Schlotheim, 1820), but pending publication of their evidence, I refer here to the name under which the species was so well figured by Lecompte.

ville's types also have no spines. Lecompte has given admirable descriptions of de Blainville's types and of Edwards and Haime's specimens, but we do not as yet know the range of variability in the species. The types are Frasnian, and I have specimens in the Jones Collection, University of Queensland, from the Frasnian of Boussu, which resemble the Western Australian specimens in all save a slightly greater obliquity of corallite growth. "*Dubia*" has, however, been recorded from the Couvinian of Torquay.

ACKNOWLEDGMENTS.

Preliminary determinations of the corals described in this paper were made at the Sedgwick Museum, Cambridge, where the author held a Senior Studentship granted by the Royal Commissioners for the Exhibition of 1851, but the paper has been written during tenure of a Research Fellowship within the University of Queensland financed by Commonwealth funds through the Council for Scientific and Industrial Research. For the loan of material she is indebted to Dr. A. Wade, Prof. E. de C. Clarke and Miss K. Prendergast; and for facilities for study to Prof. O. T. Jones and A. G. Brighton, Esq., of the Sedgwick Museum, and to Prof. H. C. Richards of the University of Queensland. The photographs of thin sections are the work of Mr. A. Barlow of the Sedgwick Museum, and those of externals are by Mr. E. V. Robinson of the University of Queensland.

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EXPLANATION TO PLATE.

All specimens are from the Upper Givetian of Lower Frasnian of the Kimberley District, Western Australia, and are from the Wade Collection now at the University of Western Australia.

Fig. 1.—*Barrandeophyllum rubrum* sp. nov. A 408a, holotype, South-eastern entrance to Mountain Home Spring Valley, Rough Range ; a, transverse section ; b, vertical section, x 1½ diameters.

Fig. 2.—The same. A 581, Napier Range, Kimberley. Oblique section, x 1½ diameters.

Fig. 3.—*Metriophyllum* sp. A 408b, South-eastern entrance to Mountain Home Spring Valley, Rough Range ; transverse section, x 1½ diameters.

Fig. 4.—*Alveolites suborbicularis* Lamarck. B 94, 10 chains East of Trig. Station K, Rough Range ; a, external view, x 1¼ diameters ; b, c, thin sections, x 1½ diameters.

Fig. 5. *Thamnopora* cf. *dubia* (de Blainville). B 92, Trig. Station J, Rough Range ; a, external view, x ⅗ diameters ; b, transverse section ; c, d, vertical sections, x 1½ diameters.


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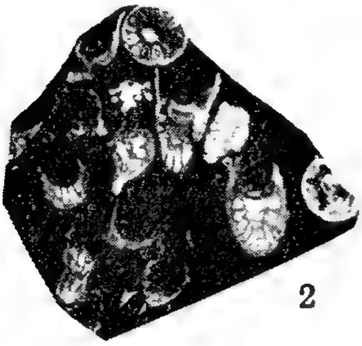
1b


4a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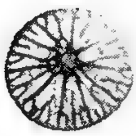
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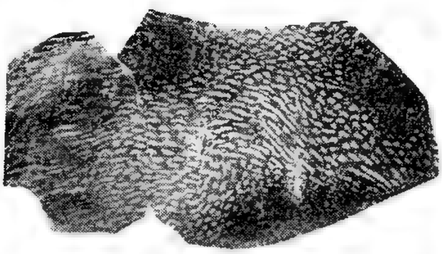
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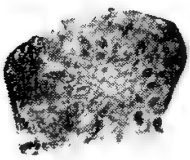
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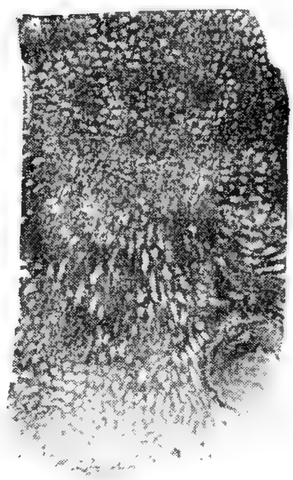
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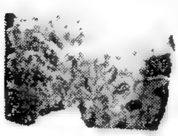
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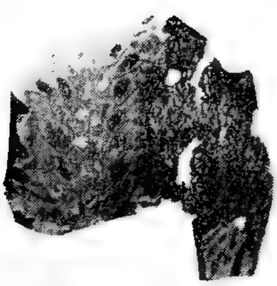
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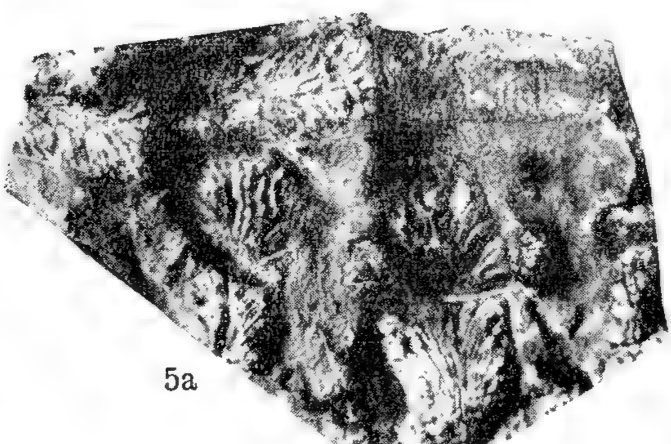
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9—A CONTRIBUTION TO THE LIFE HISTORY OF MACROZAMIA REIDLEI.*

By ALISON M. BAIRD.

Read December, 1938. Published: 1st November, 1939.

CONTENTS.

INTRODUCTION.

No full account has been published of the reproduction of Macrozamia. Chamberlain (3) described late stages of ovule and embryo of *M. Moorei.* Light (9) 1924 gave an account of the sporophyll and young ovule with details of cell formation in the prothallus.

Miss E. R. L. Reed made collections of ovules from Kalamunda in 1928-9. Miss A. Fabre in 1930 studied some phases of the development and was the first to see the living sperms in this species, but her results were not published. I am indebted to Miss Fabre for the use of her slides, particularly those of archegonia, egg, and 2-nucleate proembryo.

The present investigation has extended over several years and except for early stages in the development of the cone, all phases of the sexual reproduction have been studied. As, however, most of the genera of the Cycads have been fully investigated and the life history found to be fairly uniform within the group, only those stages which have received least attention from other writers, or in which interesting generic differences are known to occur, are described here in detail.

*M. Reidlei (Gaud.) C. A. Gardn. = M. Fraseri. (Miq.).

The material used has been collected from Crawley and Wembley (on the coastal sand plain within a few miles of Perth), and parts of the Darling Range.

MALE AND FEMALE CONES.

Fig. 1 shows a mature female cone composed of massive sporophylls, each with the single spine characteristic of the genus. This was a large cone measuring 50 cms. by 25 cms. with a weight of 30 lbs. Cones vary greatly in size and may be only half the dimensions given.

A well developed male cone (fig. 2) measures 30 cms. or more by 15 cms. just before elongation of the axis. Mature sporophylls are shown in fig. 3. Those in the lower row were taken from the tip, centre and base respectively of the same cone and show progressive shortening of the spine down the cone. Sporangia are in groups of 3-7, 5 being the commonest number.

Female cones occur singly or 2-3 per plant, and in rare instances up to 7 cones. Male plants bear 2-5 cones as a rule but 6 or 7 are not uncommon and I have found 11 cones on one plant. Both the number of cones per plant and the size of the individual cones vary considerably from one locality to another. Plants growing in the stony soil of the Darling Range, for instance, have smaller cones than those on the coastal sand plain and produce on the average fewer cones per plant.

Development of cones.

The young cones rarely become exposed before May, although coning plants can be recognised considerably earlier by the spreading apart of the leaves and the presence of a central group of densely woolly scale leaves which enclose the young cones.

Very early stages in the development have not been examined. Even in March, when the cones are still very deeply buried, the sporophylls are well developed and ovules are about 2 mms. in diameter. In both male and female cones the sporophylls are hairy outside in the early stages, becoming glabrous later.

In a young female cone, up to about the size of that in fig. 4 which measured 15 cm., the sporophylls are long and tapering, with no marked enlargement at the base where the 2 small ovules are attached. Growth from May onwards is almost entirely restricted to the lower part, which becomes steadily broader and thicker until at maturity the sporophylls measure 6-7 cm. across by 5 cm. deep with the upper part persisting as the upturned spine.

In the male cone the numerous sporophylls are very tightly packed throughout May, June and July, each sporophyll being marked by the impression of the sporangia from the one above. Shortly before the pollen is ripe the sporophyll increases in thickness at the peripheral end, and its rate of growth, particularly in a radial direction, exceeds that of the sporangia, which in consequence become less crowded and round up into a more regular shape as the pressure on the sides and top is relieved.

About the same time as the first sporangia open, there is a rapid elongation of the cone axis. The 2 cones of fig. 2 were from the same plant, the right hand one just before, and the other just after elongation. A cone measuring 32 cm. was found to have lengthened to 48 cm. in 3 days. Just

prior to this period of rapid elongation there is a loss of turgescence at the axial end of the sporophyll so that as the cone opens the sporophylls become loosely hinged at the centre. Dehiscence of the sporangia begins at the top of the cone and works downwards, pollen being completely shed usually in 3 or 4 days but sometimes spread over a longer period. On each sporophyll the sporangia nearest the axis open first—the reverse of the condition in Ceratozamia (2). The sporangia open back gradually so that the pollen is not shot out but simply falls on to the sporophyll below and drops to the ground, or is blown away.

Pollination.

At the time of pollination the female cones may measure as much as 15″ x 6″ with massive sporophylls 5 cm. across and nearly 2½ cm. thick. The sporophylls are closely packed before and after pollination but open slightly for a short period, the gaps between sporophylls averaging to 1 or 2 mm. Owing to the shape of the sporophyll there is, however, more space within the cone and a gap of sometimes 3-4 mm. between the axis and the tip of the ovule.

Pollination in Cycads is generally held to be anemophilous but there have been suggestions of insect pollination (Pearson, 1906). There seems no reason to doubt that pollen is transferred from the male to the female cone by wind, but from the outside of the cone to the micropyle is a distance of several cms., a condition very different from that in the conifers with their exposed ovules and wide open micropyles. Insects are found in the cones and play, I feel convinced, an important part in transferring the pollen from the cracks between the sporophylls to the micropyle. The tip of the micropyle projects up in a point so that an insect crawling about would tend to rub against it. A mealy bug (*Dactylopius macrozamii*) is found inside both male and female cones at all stages of their development, and a weevil and a small brown beetle are present in large numbers at the time of pollination.

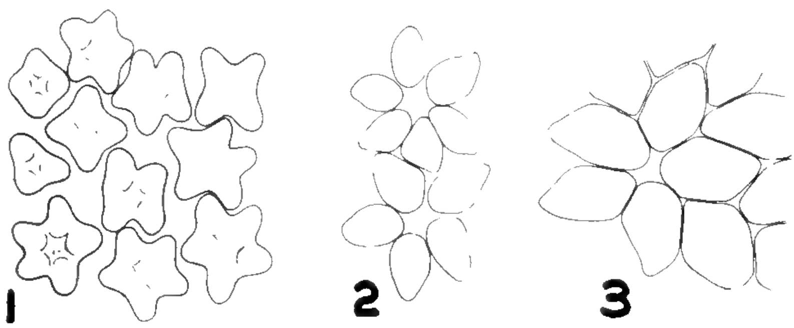
It was hoped to get some experimental evidence on the subject by sprinkling pollen on two sets of cones in one of which insects had been killed or driven out by an insecticide and comparing the resultant pollination, but the attempt had to be abandoned on account of the extreme difficulty of securing enough cones which were opened but definitely not pollinated.

I have not succeeded in finding pollination drops though doubtless they do occur. Insect pollination would not necessarily be disproved by the presence of pollination drops whose chief function is surely to draw the pollen grains down the exceedingly long micropyle.

Pollen is shed from September-October on the Coastal Plain and about a month later in the hills, and fertilization occurs four months later, by which time the cones have attained full size. Seeds are liberated February-March by the disintegration of the cone, rotting occurring at the axial end of the stalk of the sporophyll. The seeds become loosened about the same time and are usually detached from the sporophyll as it falls to the ground. If the plant is one which has developed a trunk seeds may roll for several feet but usually fall within a few inches of the parent plant and are frequently found germinating in the centre of the crown of leaves. Normally seeds lie on the ground through the whole of the next year and do not grow until after the first winter rains of the following year.

The youngest male sporophylls found were from portions of two cones dug up on March 16. The cones were 2 cm. in diameter, most of this being axis. The sporangial area could just be distinguished, measuring 1-1½ mm., but sporangia were not yet developed. Slight elevations on the surface marked the position of the centre of the sorus, and in sections these showed as heavily staining areas of meristematic cells which extended down in a wedge to link up with the vascular strands in the sporophyll. Fig. 6 shows part of a sporophyll in T.S. The same structure was described for Stangeria and Zamia by Lang (8) and Smith (12). No archesporial cells had differentiated. Subsequent history showed these cones to be far more than two weeks earlier in development than the next cones found March 31, in which the groups of sporangia were distinct. The synangial character of the sorus was very evident here, individual sporangia being little more than lobes from a central cushion—the elevation seen in the younger cones. Figs. 7 and 8 are sections through young sporangia, that in fig. 8 being slightly older. A small group of archesporial cells was present but these differed very little from the external tissues of the sporangium.

Sporangia are at the same stage of development on all parts of the sporophyll and throughout the cone. Macrozamia differs in this respect from Stangeria and Zamia but agrees with Ceratozamia.



Outline drawings of surface views of groups of sporangia—sporophylls taken from the same cone March 31st, April 14th and April 28th respectively. × 17.

Text figs. 1-3 are outline drawings of rosettes of sporangia in surface view at fortnightly intervals from March 31 to April 28, and indicate the changes in size and shape during this period. The sporangia enlarge rapidly, particularly upward and back towards the centre of the group, they become very crowded and the sides and top flattened by pressure so that the outline is almost square in T.S. The structure in May is shown in fig. 9, pl. ii., epidermis, wall of 6-7 layers of cells, the innermost already showing a certain amount of flattening, and uniform central archesporium with dividing nuclei.

A tapetum cannot be distinguished with certainty until shortly before the mother cell stage. Fig. 10, pl. ii., shows a small portion of wall, archesporium and ill-defined tapetum. There is no doubt that the tapetum is entirely sporogenous in origin. In the section of the sporongium at the stage figured some of the tapetal cells are binucleate; at a later stage this is the general condition.

A T.S. of the sporangium at the spore mother cell stage shows the epidermal cells already elongated at right angles to the surface but not yet lignified. Fig. 12, pl. ii., is taken through a L.S. of the apex of the sporangium

There may be as much as three months difference in the stage of development in plants growing in the same small area. It is obvious that with variations of this order it is only when collections are made from the same plant or from cones known to be at the same stage of development, that successive collections give the time intervals between different stages. In the case of male cones with numerous easily detached sporophylls and several cones per plant it is possible to collect over a whole season from the same plant, but female sporophylls are fewer and much larger and are difficult to remove without considerable damage to the cone. The interval between pollination and fertilisation was determined reliably this year in the case of a female plant found to be pollinated at a date when only one male plant in the locality had shed its pollen and therefore must have been pollinated from this plant. The pollen was shed on August 28th and sperms were liberated between December 28th and January 5th.

Frequency of Cone Production.

Observations made over the past few years on plants in the neighbourhood of Crawley, supplemented by more casual ones in other localities suggest that there is no regularity in cone production, or even in the growth of successive crowns of leaves. Careful records have unfortunately not been kept for long enough to give many instances of successive cones on marked plants. One female plant coned in 1930 and again in 1936, and one male in 1934 and 1938. Of about 25 plants which produced cones in 1934 or 1935 and have been kept under observation since, one male plant produced two cones again in 1938, and one male and one female are coning in 1939. In the whole area there have been cones on only five plants since 1935, and there appear to be eight or ten plants about to cone in 1939. Seedlings round two of these plants are certainly not less than 10 years old.

It seems then that for plants growing under natural conditions the interval between successive cones is usually not less than three to six years and may be considerably longer. It is probably longer in the case of female plants than male. Successive crops of seedlings round plants also furnish evidence that the average interval may be of the order of six years or more. In gardens receiving water through the summer plants may produce large and healthy female cones every alternate year, and two instances are on record of male plants coning in consecutive years.

MICROSPORANGIA.

Sporangia are more or less oval or pear-shaped with the narrow end pointing away from the centre of the sorus. When mature the wall is very hard and brittle, the epidermal cells being so heavily lignified that the cell cavity is almost obliterated. In surface view the epidermal cells are elongated in the direction of the long axis of the sporangium and have oblique end walls. In transverse section these cells are tall and narrow, becoming shorter towards the line of dehiscence. When the pollen is ripe the other layers of the wall are dry and flattened back against the epidermis. Near the apex, the epidermal cells are particularly large surrounding a slight depression occupied by a group of small lignified cells. It is this group at the end of the line of dehiscence which has been compared with the annulus of Angiopteris. Below this, and extending somewhat under the adjacent epidermal cells, is a mass of pitted cells which are heavily lignified and in striking contrast to the thin-walled sub-epidermal cells of the rest of the sporangium.

showing the lignified pitted cells and the tall epidermal cells surrounding the group of small cells in the depression. Fig. 13, pl. ii., is a photograph of a T.S. passing through the lignified cells. Nuclei are still present in these cells, whose walls become very much thicker before the sporangium is ripe. The group also becomes more extensive by thickening of adjacent cells. This figure also shows a row of cells with granular contents which occurs below the line of dehiscence.

After division of the pollen mother cells the walls of the epidermis harden rapidly and it becomes impossible to cut the sporangium by paraffin embedding methods. When the pollen grains are first formed, the tapetum is more distinct than at any other time, forming a layer of granular cells with heavily staining nuclei.

There is some disintegration of sporogenous tissue just previous to the division of the pollen mother cells. Sections show cells with small structureless nuclei among the normal archesporial cells, and in smears also these can be distinguished from mother cells by the clear nuclei and the usually less rounded shape. When division begins the microspore mother cells occupy a relatively small part of the spore cavity, the remainder being filled with liquid which stains with safranin and is coagulated by aniline blue.

MICROSPOROGENESIS.

The microspore mother cells are packed with starch grains—a condition which tends to obscure nuclear detail. Division is not simultaneous and even in one sporangium all stages may be found from resting nuclei to complete tetrads. Sporangia towards the centre of the sporophyll are slightly more advanced than those at the edges and those at the top of the cone than those at the base.

Figs. 14-18, pl. ii., are reproduced from photographs of permanent aceto-carmine smears. The long series of prophase stages can be followed well in these smears; a few are shown in figs. 14, 15 and 16. Fig. 17 and one cell in fig. 16, pl. ii., show the short thick chromosomes of the reduction division. Their tetrad nature is very apparent in some of the nuclei. Apparently some of the chromosomes are always closely associated, as chromosomes at this stage are invariably arranged in 8 or 9 groups, never 12. At the mitotic division the chromosomes are longer and more regular. Fig. 18, pl. ii., shows a cell at the anaphase of the mitotic division the chromosomes are well separated in this preparation and 24 can be counted in each cell. The ring dividing the cell is showing in the photograph.

The peculiar type of wall formation in the pollen tetrads of cycads has been described by Juranyi, Treub and Smith for Ceratozamia and Zamia. Of these stages Smith (12) gave no figures and contents herself with the statement that most stages resembled those figured by Treub and Juranyi. Particular attention has been directed to the pollen tetrads in Macrozamia, many of the details having been observed in smears of living cells. About the time the daughter nuclei are reorganising after the reduction a thin ring appears on the wall of the mother cell in the plane of the cell plate. Two mother cells fixed and stained to show the ring in its early stages are shown in fig. 19, pl. ii. The ring gradually thickens and ultimately forms a partition across

the cell by its continued ingrowth to the centre, but the wall is not complete before the anaphase of the second division. The mother cell becomes distinctly 2-lobed as shown in the photographs.

Following the second nuclear division, walls form at right angles to the first and in a similar manner, *i.e.*, by formation and ingrowth of a peripheral ring, but this wall never approaches the first in thickness. There is, however, usually a projecting plug at one or both poles of the tetrad giving it a marked polarity (fig. 22, pl. ii.). Thickening of the first partition continues until the tetrad reaches the condition seen in figs. 20-22, pl. ii. The second walls may form in the same plane or may arise at right angles to one another, tetrads of the two types occurring in about equal numbers. In tetrads at the stages shown the exine of the pollen grain is already well developed and stains with safranin in contrast to the partition framework which takes a dense stain with gentian violet or aniline blue.

The microspore mother cell wall as a whole does not thicken at all and at the 4-celled stage can frequently be seen in tetrads mounted in water as in figs. 21 and 22, pl. ii.

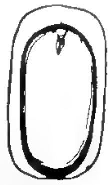
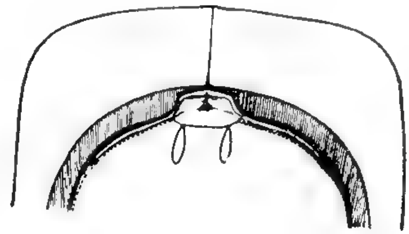
The pollen grains round up as their membranes thicken and the tetrads take the form shown in figs. 20-22, pl. ii. At this stage spores are easily detached from framework and in smears mounted in water many can be found just breaking away from tetrad as in fig. 23, pl. ii. Wall structures can be seen very well in the empty framework (fig. 24, pl. ii.). The heavy first wall is still relatively thin at the centre—very thick at the circumference. The vertical walls are similarly thin in centre with a heavier rim particularly thick where it joins the edge of the horizontal wall.

Slightly later, when the pollen grains are free, no sign can be found of this framework, and it was not until the second year of examination of tetrads that some light was thrown on the problem of its disappearance. If smears are made with sufficient care from a sporangium containing both tetrads and free spores, some groups can be found still enclosed in the mother cell wall, but with the structure of the cross walls completely destroyed. These are evidently some pectic compound which gelatinises when the tetrads are mature. Fully developed tetrads heated in water swell enormously, and the pollen grains become free, or hang together in groups of four surrounded by a structureless gelatinous mass. If the warming is very gentle it is possible to get the tetrads in a condition in which it can be seen that it is in the cross walls only that swelling has occurred. These are elongated and buckled as the whole structure is still enclosed in the unchanged mother cell wall.

The pollen grains are uninucleate when the tetrads break up, and it is not until a month later that the prothallial cell is cut off. The division of the antheridial cell follows after another 3-4 weeks and two weeks before the pollen is shed, making a total of 10 weeks or more between the formation of the pollen grains and their liberation. Some dividing nuclei were seen at each cell division but are difficult to distinguish clearly through the wall of the pollen grain. There is still liquid in the sporangium at the time of the first division in the pollen grain but the whole sporangium dries gradually before it opens. When shed the pollen grains are dry and folded in on one side, that remote from the prothallial cell, so that the grains appear elliptical. They absorb water readily however, and will rapidly swell out to the spherical form.

OVULE.

The ovule is bright red when mature, measuring 4½ cm. x 5½ x 3½ — 4, with the sides flattened where in contact with adjacent ovules.

4  5 

Text fig. 4.—L.S. Seed at time of shedding. × 1/3.
Text. fig. 5.—Upper part of ovule Dec., stony layer of integument shaded.

The seed conforms to the standard cycad type as shown by text figures 4 and 5, which give the relative proportions of the various layers. The outer fleshy integument is pigmented throughout, and is traversed by an elaborate series of anastomosing mucilage canals easily visible to the naked eye. The vascular system consists of unbranched or rarely branched strands in the outer integument and more numerous branching and anastomosing strands in the inner. The stony layer is about 1½mms. thick at the sides of the ovule and double that thickness at the base, where it is penetrated by the few main strands to the inner integument. At the apex of the seed there is a thin area surrounding the micropyle bordered by a particularly heavy rim, so forming a hollow into which the thick central region of the nucellus fits. The structure of this region of the ovule is shown in text fig. 5. This is marked by radiating lines which are conspicuous from a very early stage in the development of the ovule. The nucellus is free from the integument only in the upper part of the ovule and when the seed is mature is reduced, except in the centre, to a thin papery membrane.

Archegonia number from 3 to 9, usually 4-7, arranged in a circle round the edge of the depression at the apex of the prothallus. Several instances, however, of abnormal distribution of archegonia have been seen. In some they are in a double or triple circle at the apex, in others in an irregular group, and in one cone a number of the ovules had a very much elongated lateral group with 12-15 archegonia. Treub records a double archegonial group in Cycas circinalis as an exception. These cases of irregular and more numerous archegonia are of interest in view of the fact that in Microcycas large numbers of scattered archegonia occur.

Development of the Ovule.

The youngest ovules examined were from fragments of 2 cones collected early in March. The cones at this time are very deeply buried and only 6 undamaged ovules were obtained. These were 2 mm. in diameter by a little over 1 mm. long. The integument had already closed over the nucellus and in all except one ovule the megaspore was at an early free nuclear stage. Figs. 25 and 26, pts. II. and III., are median sections of two of these ovules.

Surrounding the megaspore there is an extensive zone of spongy tissue, which is sharply delimited from the remainder of the nucellus, and in which the cells have the appearance of sporogenous tissue with heavily staining cytoplasm and large nuclei. The spongy tissue grows with the rest of the ovule as the megaspore enlarges, but is gradually used up

and disappears by the time of cell formation in the prothallus. At an intermediate stage the outer layers are of compact cells with normal nuclei while near the embryosac the cells are degenerating. The megaspore membrane tends to pull away from this loose tissue, making fixing difficult.

At a late free nuclear stage an irregular layer, usually two cells deep, can be distinguished at the edge of the rapidly disappearing spongy tissue. These cells are granular and occasionally binucleate and constitute the tapetum. By the time cell formation in the prothallus is completed this layer consists of empty cells with suberised walls, in which condition it persists throughout the development of the prothallus.

Figs. 26 to 29, pt. III., indicate the changes taking place in the ovule between March and September. The layers of the integument gradually differentiate as the ovule enlarges, mucilage canals and tannin cells appear, the vascular strands become distinguishable and a very thick cuticle develops both on the epidermis of the ovule and on the surface of the free part of the nucellus.

The pollen chamber does not appear until shortly after cell formation in the prothallus, although that region stains heavily for some time before. A couple of weeks before pollination the passage through the nucellar beak is complete as shown in fig 29, pt. III., the remains of the beak fitting closely in the lower half of the long narrow micropyle.

From September onward the ovule enlarges rapidly, pigment develops in the outer integument and mucilage canals become very conspicuous. The stony layer hardens slowly and can be cut with a knife until early December. The whole cone is very compact and the sides of the ovules flattened by pressure. By January or February the ovule has reached its maximum size, the integument is fully differentiated and the nucellus and inner integument papery.

Ovules which have not been pollinated do not continue their development for long and the prothallus does not become starchy, but except in the case of isolated plants, failure of pollination is surprisingly rare.

Another source of abortion of the ovules is failure of the megaspore to develop. In some cones there is a high percentage of ovules which never grow beyond 2-3 cms. Until the stage of fig. 27, pt. III., these ovules develop normally except in the central region, which is cellular throughout instead of being occupied by the large free nuclear megaspore. In the absence of the megaspore the spongy tissue keeps pace with the growth of the ovule for a time, later cracks develop, and the ovule tends to collapse in at the sides

FEMALE GAMETOPHYTE.

The megaspore mother cell has not been seen. The nucellus of the smallest ovule found is shown in fig. 25, pt. II. There is in this a very narrow elongated uninucleate megaspore evidently the lowest of a vertical row, the remains of the other three showing at the upper corner. The cytoplasm is very scanty and the single nucleus small. It is possible that this was an ovule in which the megaspore was not going to develop further. In the other ovules the megaspore was at an early free nuclear stage, but fixing was not good enough for details of the nuclei to be seen. Fig. 26, pt. III., a median section of one of these ovules, shows the nucellus with the zone of spongy tissue, compact in its outer layers but made up of loose cells towards the centre where it touches the megaspore membrane.

The free nuclear period lasts from March-April to July or August. Throughout this period the increase in the amount of cytoplasm just keeps pace with the enlargement of the cell and is never more than a thin film scarcely the depth of a nucleus. The nuclei are evenly distributed through the cytoplasm and just previous to wall formation are connected by conspicuous radiating lines in the cytoplasm which forms a thicker layer at this stage. Fig. 30, pt. III., shows part of the edge of the megaspore from another section of the ovule of fig. 28, pt. III. The cytoplasm with its contained nuclei is in its natural position against the megaspore membrane and the remains of the spongy tissue lie between the membrane and the bi-nucleate cells of the tapetum.

Cell formation is initiated when the embryosac is about 7 mm. x 4-5 mm. and there are in the neighbourhood of 1,000 nuclei in the embryosac. Cell formation in the prothallus was described by Light in 1924. I was not fortunate enough to see the simultaneous mitoses, but can confirm her account of other steps in the process.

The nuclei are partitioned off by walls which form on the cell plates of the last free nuclear division, but are open to the central vacuole. At the next division walls are formed to give a layer of small cells against the membrane and a layer of open cells whose cytoplasm is in contact with the liquid of the central vacuole. When an embryosac is dissected out whole from a fresh ovule and examined in optical section this peripheral layer of cells can be readily distinguished. The living cells, cytoplasm and nuclei can be examined when such a prothallus is cut and spread out on a slide. The next layer of cells is formed in a manner similar to the first, and growth proceeds towards the centre, always with free nuclei at the inside edge of the advancing cells. With the exception of the first layer, these cells are long with very scanty cytoplasm, and apart from an occasional cross wall are only 3-4 layers deep when they meet at the centre. Cross walls form in these long primary prothallial cells from the outside inwards. One ovule examined had numerous divisions in the outer third, a few thin walls in the next third and undivided cells just meeting in the centre. The line where cells from opposite sides meet is very evident at this stage, but soon disappears. Growth of the prothallus is relatively slow so that it is not difficult to find incompletely cellular stages. Up to pollination the prothallus is very soft, but after that event becomes firmer, and within a month or six weeks starch begins to appear in the cells, first showing as a few small grains round the nucleus, then in the peripheral cytoplasm, and gradually increasing until by fertilization the cells are closely packed with large grains.

The megaspore membrane is thin in early free nuclear stages, up to cell formation the outer layer is thin in comparison with the inner. The membrane thickens rapidly during the growth of the prothallus and the outer layer, made up as in other cycads of a close pile of clubbed rods, greatly exceeds the inner one in thickness.

Archegonia.

The development of the archegonium has been fully described for other Cycads and appears to be quite typical in *M. Reidlei.* Archegonial initials appear shortly after wall formation in the prothallus and a primary neck cell is cut off from the central cell. The young archegonium has a central vacuole with a thin peripheral film of cytoplasm. The central cell nucleus

lies immediately below the pair of thin, flat neck cells. The cells surrounding the archegonium are differentiated as a jacket layer which becomes more distinct as development of the archegonium proceeds.

By the time of pollination, the archegonia are just large enough to be seen with the naked eye, but there is still a single central vacuole. In the period between pollination and fertilization the cytoplasm increases in amount and changes from a peripheral layer to a highly vacuolated mass throughout the cell, the vacuoles towards the centre being very much larger than at the edge. As the archegonium approaches maturity the cytoplasm becomes much denser and the vacuoles practically disappear. Such changes during the growth of the archegonium have been figured by Chamberlain for Ceratozamia (7) and Lawson for Bowenia (9).

The neck cells are conspicuous throughout development, showing in surface view as a pair of large semi-circular discs many times the diameter of the surrounding cells. They are astonishingly thin in comparison with their width, their depth rarely exceeding that of the contained nucleus. Shortly before fertilization the neck cells become inflated and project into the archegonial chamber as a pair of balloon-like structures easily seen under a very low magnification.

The central cell nucleus remains in position below the neck cells, but enlarges considerably. Its division was not seen, but one preparation showed what might have been the remains of the ventral canal nucleus.

The egg nucleus lies in the centre of the archegonium, and as in other Cycads is extraordinarily large, measuring 500 x 300 μ. No figures are given of the unfertilized archegonium, but its general organisation can be gathered from figs. 36 to 38, pt. III., of the proembryo. The egg membrane is thick and pitted as in other genera. Fig. 35, pt. III., shows a small part of the membrane in section with the egg cytoplasm filling the pores.

The apex of the prothallus is at first above the ring of archegonia, but flattens as the prothallus enlarges and the ring expands, and then during the month preceeding fertilization the archegonial chamber forms as a depression, reaching a depth of 1 mm. Occasionally each archegonium lies in a secondary depression.

MALE GAMETOPHYTE.

Sections of the nucellus a few days after pollination show pollen tubes beginning to penetrate the tissue surrounding the pollen chamber. The exine ruptures on the side away from the prothallial cell and a short tube with its nucleus grows out, the prothallial and generative cells remaining as in the ungerminated grain. As many as 20 (occasionally more) pollen grains are found in each nucellus. In a cone which was smothered with pollen on September 26th and sectioned September 30th over 100 germinating grains were counted in one pollen chamber. The photograph fig. 31, pt. III., was made from a thick hand section of this nucellus. The two tubes in focus show the nuclei of the generative and prothallial cells.

Shortly after this the generative cell divides into stalk and body cells, the latter small, and without the very dense cytoplasm characteristic of later stages. During the next few weeks the tubes push deeper into the nucellus, keeping parallel with its upper surface. The extent of the growth of the tubes can be followed by the lines of darkened tissue round each tube, which show on the upper surface of the nucellus. A pollen tube from a nucellus fixed November 13th, is shown in fig. 32, pt. III. The body cell

is now clearly defined with a large nucleus and dense cytoplasm. The blepharoplasts (only one showing in the section) are still small and are lying in the direction of the long axis of the tube. The prothallial cell has pushed up into the stalk cell the nuclei of the two now lying side by side, the exine of the pollen grain still adhering to the end of the tube. The tubes are packed with starch and are unbranched or have one or two short branches, little more than lobes, near the far end. The tube nucleus during the growth of the haustorial part of the tube lies near the tip, but before the sperms are formed moves back and is found at the prothallial end of the tube.

For the first three months there is little change in the pollen chamber but during the month preceeding fertilization the prothallial end of the tube enlarges and grows down through the rapidly disintegrating tissue in the centre of the nucellus. The body cell nucleus enlarges enormously and the cell becomes spherical, the blepharoplasts change from small specks to large vacuolate structures and move round through 90° to lie across the axis of the tube. No attempt was made to get a close series here. The development of body cell and blepharoplasts and the formation of sperms has been fully described by Chamberlain and Lawson for other Cycads, and the stages seen indicate that Macrozamia is in no way peculiar. The actual division of the body cell was not seen, but sections of the pair of sperms in the tube show that these are formed inside the mother cell.

Sperms.

The living sperms were first observed in January, 1930, by Miss A. Fabre and have been examined in subsequent years by the author. The sperms are of the usual type with a ciliated band round the upper part and an extraordinarily large nucleus surrounded by a narrow sheath of cytoplasm. The ciliated band is deepest at the tip diminishing towards the lower coils. The spiral band is highly refractive and stains heavily in sections. The cilia originate on the band and pass through a small amount of cytoplasm between the band and the surface of the sperm. Sperms of *M. Reidlei* measure 210-220 μ. in diameter, *i.e.,* larger than those of Cycas but smaller than in Zamia. Fig. 33, pt. III., is taken from a tube mounted whole in Venetian turpentine and shows the stalk and prothallial cells with the pair of sperms still enclosed in the mother cell. In one living pair watched at this stage, there was distinct vibration along the band but no cilia visible. As a few minutes later the cilia could be seen, it was concluded that the mother cell wall, intact at first, had been ruptured by the vibrating cilia. The mother cell wall has invariably disappeared before the sperms begin to rotate. Several pairs of sperms were watched at this stage. There was no rotation of the sperm as a whole, but the sensitive tip was slowly moving in a circle. Miss Fabre watched a pair of sperms in motion in the tube for two hours—beyond this we have no information as to the duration of the period of motility. The sperms eventually break free from each other and swim up and down the tube, rotating rapidly with the apex directed forward. They are spherical except for the beak, but are soft and readily change shape when they come in contact with the sides of the tube or jam in the narrow upper part. Fig. 34, pt. III., shows three tubes fixed after the sperms had started to move. In the tube on the left the pair has just become detached from the stalk cell, in the central one the two sperms are side by side at the base of the tube, and in the right-hand one the sperms have moved up out of sight under the nucellus.

FERTILIZATION AND EMBRYO.

The fertilized egg can be identified with certainty by the presence of the ciliated band of the sperm, usually near the top of the egg, but occasionally in the lower half, as has been found also in Dioon and Zamia. One slide only has been obtained in which the two nuclei are in contact, the smaller sperm pressing in on the upper side of the large egg nucleus. A number of slides show a single very large uniformly staining fusion nucleus. The actual division of this was not observed. The cytoplasm of the fertilised egg is smooth and dense, except for a disturbed area which marks the passage of the sperm nucleus.

The entry of the sperm into the egg has been described by Chamberlain for Dioon and by Lawson for Bowenia. As in those genera, the neck cells in Macrozamia are still intact after the entry of the sperm as shown in fig. 36, pt. III. In some fertilized eggs there is, immediately below the neck cells a heavily staining mass which, in fresh ovules, shows as an oily substance. This was noticed by Treub in Cycas. It seems likely that this is the remains of a second non-functional sperm. The one in fig. 36, the only recognisable second sperm seen in an egg, is already showing the red staining characteristic of disorganising tissue. No case of several sperms inside one egg, as recorded for Stangeria and Bowenia, has been found.

Early divisions apparently take place in rapid succession as of numerous eggs sectioned practically all had the single fusion nucleus or a large number of free nuclei. Only one two-nucleate proembryo has been seen. In ovules containing multinucleate proembryos, some of the eggs, presumably those which have missed fertilization, have a large central vacuole and smaller ones in the lower part. At later stages these archegonia are left as empty shells, the egg membrane still retaining its shape.

Free nuclear stages of the proembryo show the nuclei evenly dispersed through the smooth cytoplasm. Several preparations were obtained showing simultaneous mitoses in the proembryo. The L.P. photograph, fig. 38, pt. III., was taken from one of these sections. As in other cycads, the division figures are remarkably small in comparison with the resting nuclei.

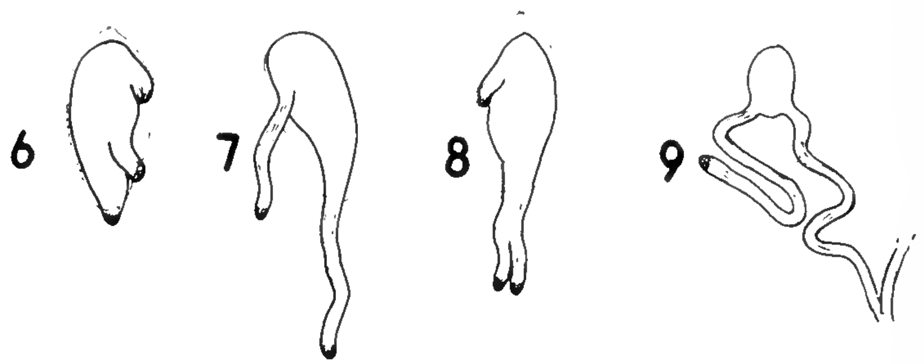
Fig. 37, pt. III., shows nuclei at the apex of the proembryo after one of the late divisions. The neck cells are in the collapsed condition found soon after fertilization. The cytoplasm is becoming visibly vacuolate again. No sign of evanescent walls has been seen before the true walls form (*cf.* Dioon.)

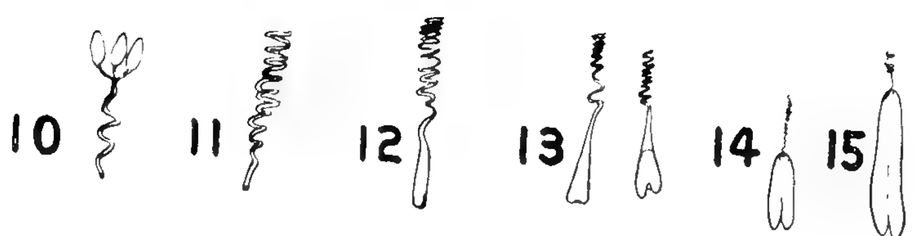
Wall formation takes place throughout the proembryo except for a small region in the centre, which remains non-cellular with free nuclei. This region breaks down about the time the embryo is beginning to differentiate, leaving a hollow cavity, which is shown in fig. 41, pt. III. In *Cycas circinalis* (14) *C. revoluta* (Ikeno) the breakdown of the central tissue occurs much earlier, even before cell formation, so that the nuclei are restricted to a peripheral layer of cytoplasm and the cellular tissue when it does form is never as extensive as in *M. Reidlei.* In *M. Moorei* the proembryo is completely cellular, also in Encephalartos. Probably a series could be traced through species of Cycas, Macrozamia and Encephalartos, showing progressively earlier wall formation in relation to the appearance of the central cavity.

There are further divisions in all parts of the cellular proembryo, but these are not simultaneous. In one set of preparations most nuclei were dividing in the upper part while those in the lower were resting. These gave a good series of mitotic figures, one of which is shown in fig. 39, pt. III. The chromosomes are straight and slender.

The embryo proper develops as a result of active division of a few cells at the base of the proembryo and the suspensor from the cells immediately above these. Fig. 41, pt. III., shows the suspensor cells just distinguishable above the small mass of embryo cells. Elongation of the suspensor pushes the rest of the proembryo back into the egg and the embryonic tip down into the prothallus. In fig. 42, pt. III., the suspensor has begun to elongate and the embryo has just broken through the egg membrane (showing as a dark line round the proembryo). The central cavity has now reached its maximum size. The archegonial membrane retains its shape and can be dissected out and handled with ease until the time when it is crushed back by the enlarging embryo.

In *Macrozamia Reidlei* from 1-3 lateral embryos have been found in addition to the normal basal embryo. These develop in exactly the same way as the basal one, *i.e.*, from a small group of actively dividing cells in one particular region of the periphery of the proembryo. Development in these apparently does not proceed very far, as they have only been observed at early stages. When lateral embryos have just begun to elongate they are still inside the egg membrane and are likely to be missed if this is not





Text figs. 6-9.—Diagrams showing four different examples of several embryos developing from one zygote. (Dotted line indicates the position of the egg membrane.)

Text figs. 10-15.—Diagrams showing development of the embryo; fig. 10—March, 11—May, 12—July, 13—September-October, 14—December, 15—February. (14 and 15 half previous scale.)

removed before examination of the embryo. Four different arrangements of multiple embryos are shown in Text figs. 6-9. In Text fig. 8 there is one small lateral and two equally developed basal embryos, which in this

case appear to represent simply a forking of a single suspensor. Branching of the suspensor has been recorded by Saxton for Encephalartos, and it would be interesting to know if lateral embryos also develop in this genus. It is only in those genera in which the proembryo consists of uniformly cellular tissue that polyembryony of exactly this type could arise. The condition is not rare in *M. Reidlei* as it was found in about half the ovules examined from two cones, occurred in two others of those examined in 1937, and was seen in seeds from two cones dissected this year.

Embryos from several archegonia meet and their suspensors become closely associated. One embryo, however, grows more rapidly than the others, which are left behind at various levels up the suspensor. As growth proceeds, the number of cells across the embryo, and correspondingly, the width of the suspensor, increase. The upper part of the suspensor dries and its coils are pressed back against the micropyle, so that in later stages only the lower most recently formed part is turgid. It would seem that the significance of the long suspensor is the insuring of the existence of a turgid length of suspensor, which up to a point increases in thickness with the increasing size of the embryo. It must be remembered in this connection that the embryo is growing in the endosperm for over twelve months after the seed has been shed. The average length attained by the suspensor is about 9 cms. From March to June the embryo remains a small mass of cells at the end of the elongating suspensor, July to September there is a noticeable enlargement, and by October cotyledons are just forming in most seeds. Not long after the appearance of cotyledons meristematic activity begins at the suspensor end to form the coleorhiza and root apex. The cotyledons close over the stem apex and grow steadily down through the endosperm, ultimately occupying two-thirds of the length of the seed. Text figs. 10-15 show the growth of suspensor and embryo at intervals from March to February. During this period development lags in a number of seeds, most of which will never be capable of germinating.

The number of cotyledons is normally two, but two embryos with three have been seen, one at an early stage when the cotyledons had just appeared and the other in a mature seed.

The very interesting results of klinostat experiments by Sister Helen Angela suggested that the single cotyledon in Ceratozamia might be related to the fact that seeds were shed before the cotyledons developed and were lying in a horizontal position during the development of the embryo. If that is true, the suppression of one cotyledon has not followed early shedding in Macrozamia and Cycas, both of which shed their seeds some months before cotyledons appear.

GERMINATION AND SEEDLING.

There is no dry or dormant stage in the development of the seed. By April or May most embryos have reached the maximum size attained inside the seed, and the coleorhiza is pressed back against the thin area of the testa surrounding the micropyle. The radiating lines in this area mark definite structural weakness which has been increased by a certain amount of decay during the year on the ground, so that when the root is forced against it the testa cracks open into a number of wedge-shaped pieces readily forced apart by the growing embryo.

The embryo pushes out until the cotyledons are 1 cm. beyond the end of the seed, but without any elongation of the root. This growth is quite independent of external moisture and takes place equally well in seeds

which have been kept on a shelf in the laboratory or enclosed in boxes. Unless moisture is available at this stage however, no further growth can take place—seeds which have started to germinate before the winter rains shrivel and die—but under favourable conditions the root next begins to grow and breaks through the fibrous coleorhiza.

Thus, in the present year, seeds which germinated at the end of April produced roots which grew slowly through the winter, being 5-8 cm. only in August, the first leaf appearing early in November, by which time the roots were 20-25 cms. long. As in other Cycads, young plants grow very slowly, producing but a single leaf annually for many years. The seedlings in fig. 5, pt. I., are one and two years old respectively. Since the seeds germinate on the surface, while plants four or five years old have the stem apex several inches below ground level it is evident that the tap-root must contract considerably during its growth. In the juvenile leaves the pinnae are serrated near the tips, as in many other species. The number of pinnae increases in successive older leaves but varies considerably in plants of the same age, and is quite unreliable as an indication of the age of a young plant.

The anatomy of the seedling was not investigated beyond the determination of a solid cotyledonary vascular plate as in other genera and the usual girdling leaf traces.

CONCLUSION.

The general course of the life history and the structure and development of the reproductive organs, as described above for M. Reidlei are typical of the cycads as a whole. A point of rather special interest in Macrozamia is the occurrence of a type of polyembryony not, as far as I know, previously recorded. The development, structure, and ultimate dissolution of the partition walls in the pollen tetrad have also been shown to present features of extraordinary interest.

In certain features, viz., the high spore output per sporangium and large number of nuclei in free nuclear stages; the advanced condition of the female prothallus at the time of pollination; undifferentiated proembryo, immature state of the embryo when the seed is shed, and comparatively small sperm, Macrozamia is probably correctly considered as one of the more primitive cycads.

Comparison has been made with other genera throughout the paper and it is suggested that the affinities of Macrozamia are with Cycas and Encephalartos, being probably closest to the latter, which it resembles in general habit and structure of cones and seeds. In this connection it is worthy of note that Cycas (Australia and Orient) and Encephalartos (South Africa) are its nearest neighbours geographically.

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ILLUSTRATIONS.

Plate I.

Fig.

1. Mature female cone—February.
2. Male cones: that on the right just before, and on the left just after the elongation preceding the shedding of the pollen—October.
3. Male sporophylls:—the L.H.S. upper one with sporangia open after shedding pollen. The lower row from left to right shows sporophylls from top, centre, and base of a cone. On the L.H.S. sporophyll a few sporangia are open.
4. Young female cone and two detached sporophylls with minute ovules—April 10.
5. Seedlings one and two years old respectively.

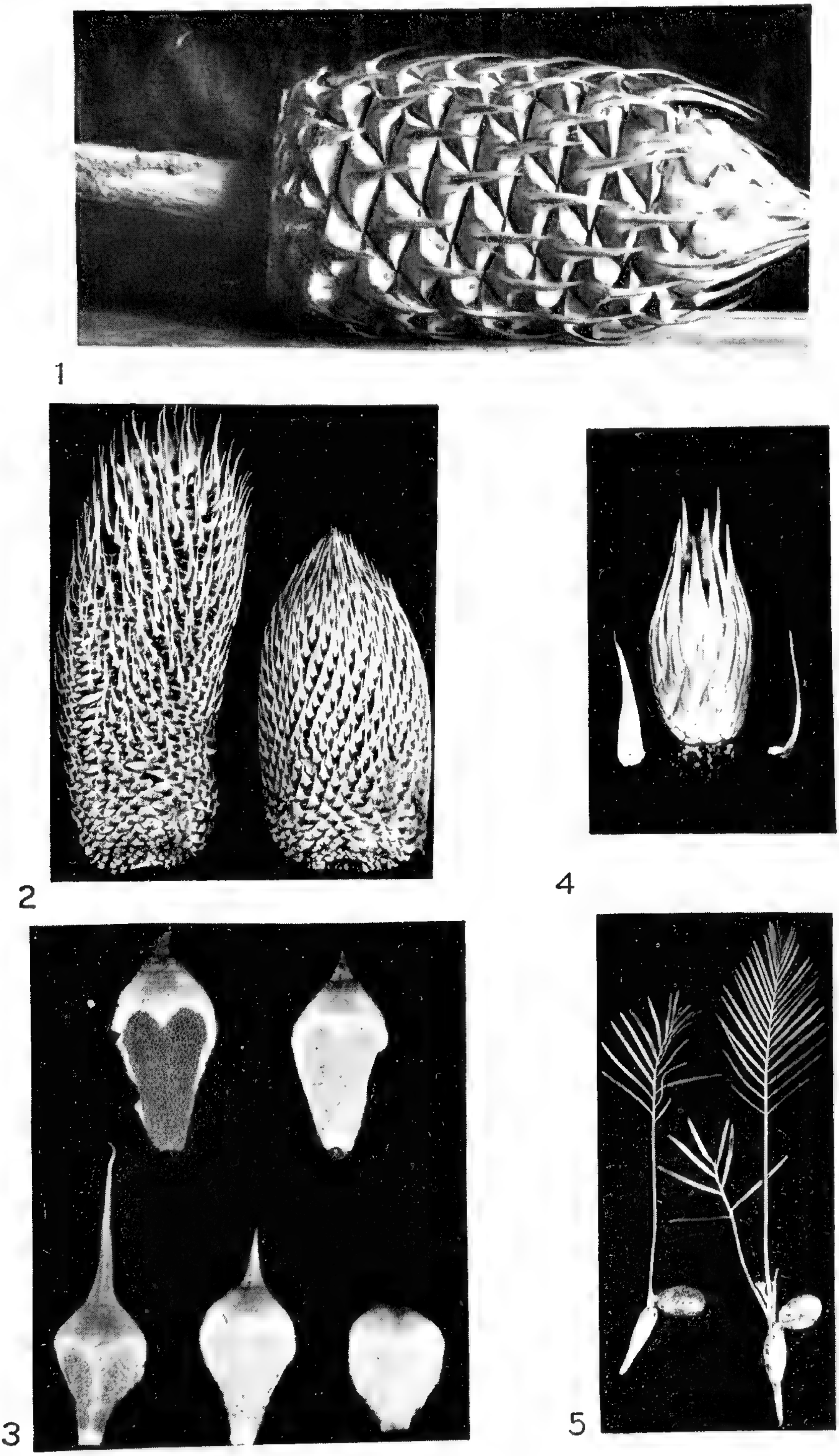

PLATE I.

Plate II.

Fig.

6. T.S. young sporophyll showing early stages of sorus; meristematic areas running down to the vascular strand of the sporophyll. × 70.
7. Section through sporangia at the stage of text fig. 1—March 31. × 70.
8. Section through slightly older sporangia. × 70.
9. T.S. sporangium—May 11.
10. Part of wall, tapetum and archesporium—May 26. × 175.
11. Same at Megaspore mother cell stage—June 9.
12. L.S. apex of sporangium.
13. T.S. same region passing through group of lignified cells.
14. }
15. } Prophase stages of 1st division in the pollen mother cells. × 385.
16. }
17. Chromosomes of the meiotic division.
18. Chromosomes at anaphase of mitotic division in the daughter cells.
19. Pollen mother cells stained to show early stages of the ring.
20. }
21. } Pollen tetrads photographed from unfixed smears.
22. }
23. Pollen grains just becoming detached from the framework of the tetrad.
24. Empty framework of a tetrad in which the second walls are at right angles to one another, and a pollen grain in optical section showing exine and intine.
25. Median section of central part of young ovule showing part of integuments, nucellus, and spongy tissue.

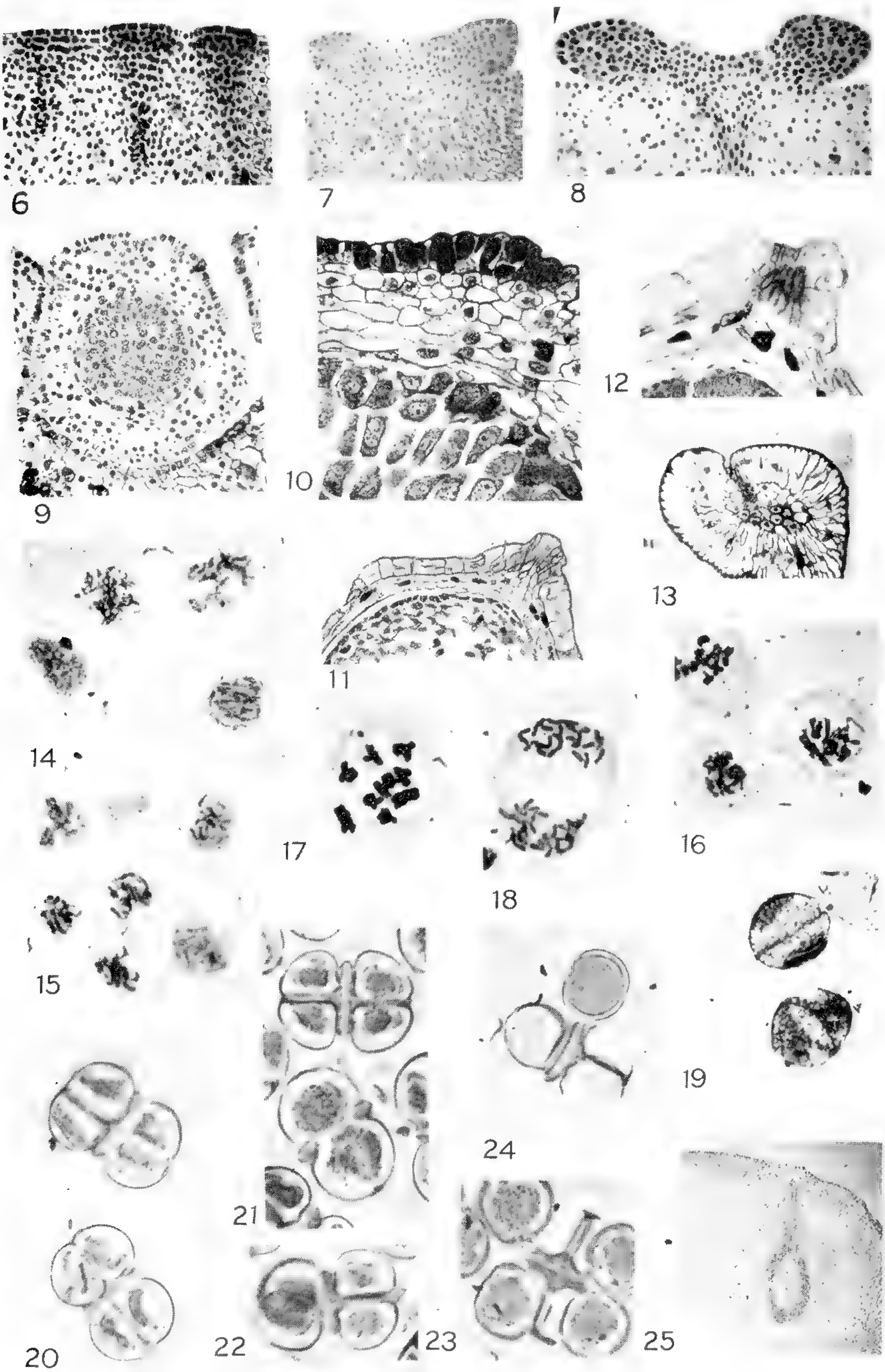

PLATE II.

Plate III.

Fig.

26. Median L.S. young ovule, early free nuclear megaspore March 16. × 6.
27. L.S. slightly older ovule, megaspore membrane shrunk into the centre of the ovule. × 8.
28. Ovule with free nuclear embryosac just before cell formation—May. × 6.
29. Upper part of ovule shortly before pollination, nucellar beak in micropyle, pollen chamber, tapetum, megaspore membrane—October. × 8.
30. H.P. of small portion of ovule of fig. 27 showing cytoplasm with free nuclei against megaspore membrane; remains of spongy tissue, tapetum and the edge of the nucellus. × 175.
31. Pollen grains germinating in pollen chamber four days after pollination.
32. L.S. nucellus with pollen tube, showing exine of pollen grain; prothallial cells; body cell with large nucleus, dense cytoplasm and blepharoplast.
33. Photograph of whole tube with pair of sperms. × 80.
34. Three tubes fixed after the sperms had started to move.
35. Small section of egg membrane showing cytoplasm of egg in the pits, jacket cells outside.
36. Apex of archegonium shortly after entry of sperm.
37. Apex of free nuclear proembryo.
38. Multinucleate proembryo with dividing nuclei.
39. Cellular proembryo showing absence of cell walls in centre. Section torn.
40. A dividing nucleus from a cellular proembryo.
41. Differentiation of embryo, suspensor cells just beginning to elongate above embryo proper, central cavity formed.
42. Young embryo and suspensor.

Figs. 36 and 37 × 70. Figs. 38, 39, 41, 42 × 11.

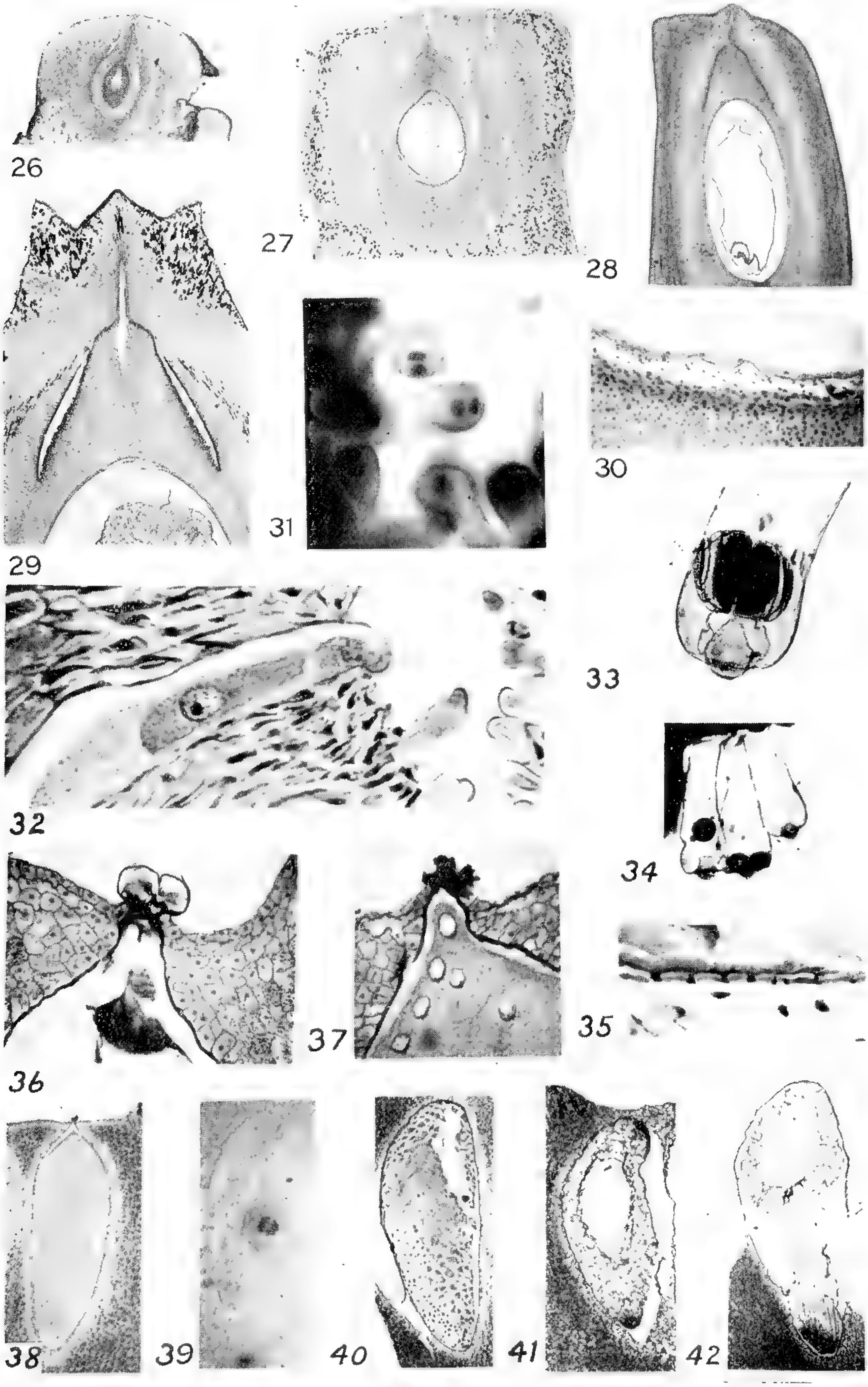

PLATE III.

By Authority: Fred. Wm. Simpson, Government Printer, Perth.

10.—THE DONNYBROOK SANDSTONE FORMATION AND ITS ASSOCIATES.

THEIR RELATIONSHIPS AND PLACE IN THE STRATIGRAPHICAL SEQUENCE.

By
A. GIBB MAITLAND.

Read: 9th May, 1939; Published: 23rd February, 1940.

CONTENTS.

INTRODUCTION.

During the course of researches into the constitution, structure, organic remains, mineral deposits, and correlation of the geological formations of Western Australia, I have been led to investigate, both in the field and the study, the stratigraphical unit and its associates, which forms the subject matter of the title of this paper.

In the hope that the results of these studies, which relate to the stratigraphical position of this geological unit, may be of use to other scientific workers in somewhat similar investigations, I have been induced to bring them before the members of the society, for as will be inferred from the text, they are of more than mere local interest.

Attention has often been directed to the circumstance that in many geological investigations rocks of any particular formation are noticed long prior to their allocation to any definite system of historical nomenclature, and facts regarding them are recorded without referring the beds to any special stratigraphical horizon.

Although the Donnybrook Sandstone appears to have been unknown as a formation prior to 1912, references were made to it some years previously.

The area over which it extends is however not an entirely unknown region; it is replete with geological facts and also with difficulties.

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The literature relating to the Donnybrook Sandstone and its Associates is comparatively voluminous, for no less than forty-eight papers dealing with the matter have already been prepared by several observers and the results published in English, French and German. A list is given in the bibliography.

Despite the fact that since the beds were first examined in the middle of last century no unequivocal determination of their absolute geological age appears to have been arrived at.

HISTORICAL.

In the year 1898 Mr. T. Blatchford prepared a report "Gold Discoveries at Donnybrook," in which brief reference was made to the geological features of the area covered by his investigations. After a second visit, this officer extended his investigations over a wider area, and in a report "On the Development in Mining in the Locality of Donnybrook," published in 1899, noted for the first time the occurrence of an extensive deposit of sandstones, shales and conglomerates, together with coal seams, lying beneath the cover of superficial accumulations. No direct evidence, however, as to the age of the sedimentary series was forthcoming. This report, which was accompanied by a geological sketch map and section showing the known extent of the sedimentary rocks, described the occurrence of gold, of secondary origin, in certain ore bodies by which the unaltered sediments were traversed.

The name Donnybrook Sandstone appears to have been definitely applied to this unit as a formation by Mr. E. C. Saint Smith in 1912, in a report published by the Geological Survey as Bulletin 44, under the title "A Geological Reconnaissance of Portion of the South-West Division of Western Australia," which, *inter alia*, summarised the available data regarding the district. This author described the rocks as consisting of almost horizontally bedded sedimentary rocks associated with shales and coal seams, of the geological age of which no conclusive evidence was adduced though he referred them doubtfully to the Mesozoic (?) Era. Mr. Saint Smith noticed that the beds of Donnybrook bore a striking resemblance in their lithological characters to the strata occurring in association with the coals of Collie, which have been regarded as belonging to the Permo-Carboniferous System.

Mr. H. P. Woodward in 1916 continued the survey of the south-western portion of the State inaugurated by the work of Mr. Saint Smith, and in his report, "Notes on a Portion of the South West Division" published in the same year, referred to the presence in the area to the east and south of the Collie Naturaliste Scarp to the eastward of the Dunsborough-Augusta Scarp of a tilted and block faulted plateau made up of sandstone, shales and coal seams of the Donnybrook Series. Mr. Woodward likewise refers to the discovery of basins of the Collie Donnybrook Series to the eastward of Donnybrook itself. In the concluding portion of his report the hope was expressed that the field work would be continued during the following season, but Mr. Woodward's death after a very brief illness in the early part of 1917, necessitated this important investigation designed to work out its detailed stratigraphy, so as eventually to furnish a clear narrative of the whole of the geological history of the south west corner of the State, in its economic bearings being suspended. Though no definite age was assigned to the Collie-Donnybrook Series it is quite clear from Mr. Woodward's references to the Collie Coalfield in an earlier report on "The Coal Resources of Western Australia" published in 1915, that he inclined to the belief that it is "either old

Mesozoic or intermediate between that and the Palaeozic" This falls in with that originally enunciated by him in a report issued in 1891 that the Collie River beds were of an early Mesozoic Age; a conclusion which he reached from a study of the physical aspect of the field and the chemical composition of the coal seams. In his "Notes on the Geology of Western Australia" which appeared in the Geological Magazine during 1894, Mr. H. P. Woodward, however stated:- -

> "A small patch of the Upper Carboniferous formation has been discovered upon the Collie River, consisting of shales, sandstones and coal seams. It is probably one of a series of small basins lying to the eastward of the range . . ."

It becomes desirable at this stage to give consideration to the diverse views which have been held as to the precise position the formation holds in the geological time scale, involving as they do some yet unsettled points of classification. This question is one about which there has been considerable divergence of opinion, for some authorities have assigned an early Mesozoic and others a Permo-Carboniferous Age to which latter has now with general accord been, on scientific grounds, relegated to the Permian System.

Several weeks in the early part of 1898 were devoted by the author to a geological survey of the Collie Coalfield, during the course of which every locality where any section of the rocks could be seen was visited. Owing to the surface being covered by recent superficial deposits, sections could seldom be seen, and were only noticed along the lines of most rapid erosion, the watercourses. Sufficient evidence was not obtained during the field investigations to enable any statement as to the age of the beds to be made, and no recognisable fossils were found. The results of this survey were published in 1899 and the report included a geological map and sheet of bore sections.

In an address entitled "Recent Advances in the Knowledge of the Geology of Western Australia" delivered by myself to the Section of Geology at the Adelaide meeting of the Australasian Association for the Advancement of Science in 1907, the question of the precise age of the Collie River beds was reviewed in the light of new evidence which had then become available, and involved a necessary rectification of the earlier view. The conclusions drawn from this revision were stated in the following words:—

> "In view of all the evidence at present to be deduced from the plant remains and the marine organisms in the beds associated with the Collie coal seams, despite the nature of the coal and the physical characteristics of the basin, I am constrained to admit that a Permo-Carboniferous Age of the Series presents the strongest claims to acceptance."

Mr. E. F. Pittman, the Government Geologist of New South Wales, after a brief visit to the State referred in his report, "Notes on the Geology and Mineral Resources of portions of Western Australia" published in 1898, the Collie River beds to the Mesozoic Period. Mr. Pittman advanced this view after an examination of certain fossil plant remains he collected had been made by Mr. R. Etheridge, junr., Palaeontologist to the New South Wales Geological Survey and the Australian Museum, and determined by him (with hesitation) as the genus *Sagenopteris* one of the typical Mesozoic fern-like forms. Some years later Mr. Etheridge re-examined the doubtful Sagenopteris and in a report, "Plant Remains from the Collie Coalfield" published in 1907, amended his previous determination, and looked upon it as *Glossopteris*, thus re-assigning the age of the beds to the Permo-Carboniferous Period.

In an important report by Dr. R. L. Jack published during 1905 and prepared by him as Royal Commissioner on the Collie Coal Industry under the terms of which he was instructed to include geological considerations, it is stated that the area occupied by the coal measures amounted to about 50 square miles. This author also pointed out that between the coal seams are alternations of shales, sandstones, and grits, the shales being less argillaceous and the sandstones less coherent than is customary among the Carboniferous or Permo-Carboniferous formations of Europe, Africa, and Australia.

The stratigraphical position of the Collie River beds is especially referred to in paragraph 14 of the report in these words:—

"The evidence bearing on the age of the coalfield is at best inconclusive. High authorities have indeed expressed the opinion that it was of Palaeozoic Age—Carboniferous or Permo-Carboniferous—but all these opinions are founded exclusively upon the presence of the fern Glossopteris which is now known to range from Carboniferous up to late Cretaceous. The shales are coarse-grained and incoherent and badly adopted for the preservation of plant remains, and of all the fossils that I have seen I venture to think that few palaeontologists would be bold enough to say more than that they are Glossopteris or something like it. Several observers have informed me from time to time that they have seen fossil plants which, whatever they were, were not Glossopteris, but none have yet succeeded in bringing them, in a recognisable condition under the notice of any palaeontological authority."

A geological map and cross section accompany the report, and upon the map the age of the coal measures has been set down as undetermined. Dr. Jack makes reference to the entire absence of igneous dykes penetrating the coal measures, and concludes from this that the strata were deposited after the cessation of volcanic activity, and therefore at a somewhat later epoch. This deduction was probably drawn from the fact that evidence of igneous activity was present and had been discovered in a bore hole (Diamond Drill Bore No. 5) situated some little distance outside the western edge of the coal measures in Ironstone Gully. This bore, after passing through surface soil, etc., ferruginous sandstone and conglomerate, encountered an olivine-diabase at 91 feet 6 inches from the surface; operations were discontinued at a depth of nearly 97 feet without meeting with the rocks beneath.

Since the publication of the earlier papers the work of Mr. F. Chapman, Palaeontologist to the National Museum, Melbourne, resulted in considerable additions to our knowledge of the fossil fauna and flora of the Collie River beds. This gentleman concluded in an official report, "Notes on Fossils from the Collie Coalfield in the Collection of the National Museum, Melbourne," published in 1907, that an examination of the collection of fossils from the beds between the coal seams at Collie forwarded by the Premier of Western Australia, the plant remains and the associated foraminifera pointed in a general way to a Palaeozoic Age of the strata.

The month of April, 1914, saw the appointment of a second Royal Commission on the Collie Coal Industry under the chairmanship of Dr. W. G. Woolnough, the Professor of Geology in the University of Western Australia. The published report of the Commission, which was accompanied by a geological map of the Collie Coal Basin, states that the main facts regarding the geology of the area, so far as the Commissioners understood them, were:—

(a) the sediments and coal seams forming the Collie Coal Measures probably covered a greater area than their remnants occupy at the present time and were deposited in Permo-Carboniferous time;

(b) they were in all probability continuous with the Donnybrook Sandstones of the south;

(c) the area of the Collie Coal Basin was much greater than had been suspected in 1905 at the time the report of the first Commission was issued;

(d) the dominant structural features were a complicated fault system uninterrupted for many miles and responsible for the approximately rectilinear form of most of the boundaries of the basin;

(e) the occurrence of beautifully preserved leaves of the fern-like plant *Glossopteris* in association with the coal seams.

A considerable difference appears in the outline of the north-eastern boundary of the basin in the 1916 map, and that defined by Dr. Jack in 1905, though the two Commissioners are in close agreement regarding the north-western and south-western limits.

Dr. E. S. Simpson, in a report published during the year 1917, dealt in some detail with "The Chemical and Physical Properties of some of the Donnybrook Sandstones" in which it was briefly stated that the geological age of the sandstones was unknown.

A report of Mr. F. G. Forman on an "Inspection of Gold Prospecting at Donnybrook" issued in 1935 briefly refers to the Donnybrook Sandstone as being of Permo-Carboniferous Age. This author points out that these beds rest upon the ancient crystalline and metamorphic sedimentary rocks. Reference is likewise made to the occurrence of gold in the sandstones associated with fracture zones or joint planes filled with chalcedonic silica, producing a rock resembling quartzite. The gold is stated to be of secondary origin, the parent source being in the older underlying crystalline and allied rocks, which are traversed by quartz reefs, responsible for the yield of 841.76 ounces of gold by crushing 1,653.30 tons of ore.

The organic remains hitherto found in the Donnybrook Sandstone Formation are only few, and the palaeontological data relied upon by most of the observers referred to in considering the geological age of the strata was almost exclusively based upon the occurrence of the fern-like plant *Glossopteris*, which is now known to have a vertical range from the Carboniferous up to the Triassic Period.

The importance of foraminifera as a palaeontological aid to correlation is now generally recognised; of these there have been recorded from the Collie Series, one species of the family Lituolidae, two belonging to Textulariidae, and two of the Rotaliidae. The genus Valvulina from Collie, which ranges from the Palaeozoic Period to the present day, has a large development in Cretaco-Tertiary formations elsewhere but is somewhat rare in Triassic strata, though those which are identifiable appear to have kinship with such as made their first appearance in Palaeozoic times. The presence of the depauperated genera of foraminifera, which have been recorded from some of the sandstones associated with the coal beds of Collie, while of importance in itself does not indicate an absolute identity with strata of undoubted Palaeozoic Age elsewhere.

The analytical examination of the early investigations has been necessary in order to set out the facts in their proper perspective, and in addition to do justice to those who have observed and described so much.

Having in this historical review given a brief *aperçu* of the principal original observations made upon the rocks, and the evidence used in considering their geological age prior to the subdivision given the name it now bears, it is proposed to describe the formation more minutely, not only as regards its distribution, characters, stratigraphical relations to underlying and overlying formation, together with some of its problems and to discuss its correlation, both intercontinental and long distance for this latter represents one, if not the chief scientific objective to which an investigation of the aspects previously enumerated inevitably leads.

DISTRIBUTION OF THE FORMATION.

The country in the vicinity of the township of Donnybrook—situated in the extreme south-west corner of the State, between Geographé Bay and Greenbushes tinfield, on the Bunbury to Bridgetown railway line—is for the most part covered with laterite, and other superficial deposits, which effectually conceal the underlying rocks, except in the gullies and on the hill-slopes.

Lying beneath this ubiquitous cover is a widely spread deposit of almost horizontal rocks, which consist of fine-grained sandstones, alternating with bluish-grey pyritous clay shales (one of which contains a seam of iron pyrites six inches in thickness), coal seams and conglomerates. The basal beds are very arenaceous, and lithologically virtually arkoses. The uniformity of the series in respect to its lithological and other characters, constitutes one of its striking features.

The beds rest upon the ancient crystalline and metamorphic rocks which make up the complex of the Darling Range, as developed in this portion of the South-West Division. Outliers of the series have been met with in several of the hills in the watershed of a north and south tributary of the Preston River, which points to the probability of the contact being of deposition, rather than one of faulting as had previously been suggested.

DESCRIPTION OF THE DONNYBROOK SANDSTONE AND ITS ASSOCIATES.

These sedimentary rocks, which cover a considerable portion of the south-west corner of the State, form a distinct stratigraphical unit, appropriately named The Donnybrook Sandstone from the fact that some of its component beds have been extensively exploited in the neighbourhood of the township of that name. The series is, however, practically confined to the maritime and coastal portions of the South-West Division, and does not appear to have spread over the vast interior of Western Australia.

Mining operations have been carried out in the Donnybrook Sandstone Series within an area lying to the south-west of the township near the head-waters of the Capel River, not far from that powerful fault which forms the southern extension of the Darling Fault Scarp. These operations disclosed the occurrence of impure brown coals of low calorific value, at relatively shallow depths associated with sandstones and shales. Some of these coals, which have an average thickness of about ten inches, at times exhibit traces of lignitic structure. The seams are separated by a similar thickness of sandy and carbonaceous shales.

The series has been penetrated to a depth of 202 feet from the surface in a shaft (Murphy's Shaft) sunk on Prospecting Area 155H, about four miles south of Donnybrook. The shaft exposed the following section:—Gravel and laterite, 8 feet; clay shales, 65 feet; lignite (with shaley bands), 4 feet; sandstone, 10 feet, and loose sandy grit, 12 feet. A bore carried down from the bottom of the shaft passed through 18 feet of sandy shale. The calorific value of six samples taken from the seam of brown coal varied from 5,710 to 6,928 British thermal units.

In addition to the prospecting for coal, quarrying operations have been carried on in the vicinity of Donnybrook on a fine-grained felspathic sandstone, which has been extensively used in many buildings in the metropolis. A number of quarries have been opened during recent years in these gently inclined sandstones at several localities lying within a belt about eight miles in length, which extends from about four miles due north to about four miles south of the Donnybrook Railway Station. The quarries are nearly all situated along the western flanks of the Darling Fault Scarp at a moderate elevation above the general level of the country to the westward at about 200 feet above sea level. The sandstones dip at an angle of about four degrees in a general south-westerly direction.

Geological evidence bearing upon the probable extent, constitution, and structure of the Donnybrook Sandstone Series being incomplete, the Government, during the year 1911, deemed it expedient to have a more or less detailed examination of the area covered by these beds undertaken. The thickness of the formation, as well as the classification of the associated beds, have very many important scientific and economic bearings. The base of the formation has been, but seldom, observed.

The Donnybrook sedimentaries cover a wide extent of country to the westward, where their presence has been proved by the bores put down in the valley of The Vasse River which enters Geographe Bay near Wonnerup some miles to the north of Cape Naturaliste. Bore No. 5 near the eastern bank of the Vasse River, to the south of Busselton, passed through the whole sedimentary series and entered the Pre-Cambrian crystalline rocks at 655 feet below the surface, and bore No. 6 at Newtown reached the floor of crystalline rocks (gneiss) at a depth of 330 feet. These beds were also met with to the northward in No. 2 bore on the Dardanup Estate, in the valley of the Fergusson River. This bore was carried down to a depth of 1,032 feet without the base of the formation having been reached.

What is believed to be the northward extension of these beds has been met with in the experimental borehole put down at Cookernup in the watershed of the Harvey River, about 35 miles to the north of Dardanup. The bore was situated just to the south of the railway station in the township and carried down to a depth of 2,215 feet, through sandstones, grit and shales, without the base of the formation having been unequivocally reached, although from the nature of the core samples it seemed that bedrock could not be very far off. The results obtained from this experimental bore, which was carried out with a Calyx drill, demonstrated the great extent of the formation in a northerly direction from Donnybrook. No organic remains were noticed in the cores submitted, and no coal seams recorded.

The Donnybrook Series extends as far south as Fly Brook, a tributary of the Donnelly River, on the South Coast, about 30 miles east of Cape Leeuwin. The series is made up of beds of sandstone, grit, micaceous clay shale, with seams of coal, which are overlaid by a coarse conglomerate containing large water-worn pebbles of quartzite, quartz and crystalline rocks. A considerable amount of shallow boring has been carried out in this area, the deepest borehole being 128 feet, and in it 17 seams of coal, aggregating 20 feet in thickness, were passed through. The largest seam was five feet four inches thick, with a clay parting of six inches, whilst another seam two feet three inches had a clay parting of two inches. The Fly Brook seams are lustrous black coals with a fracture somewhat resembling jet, though lacking its hardness, whilst a woody structure was clearly visible in the weathered surfaces. The calorific value of a sample of the five feet seam, proved to be 10,167 British thermal units. The coals of Fly Brook bear a resemblance to some of those of the Collie field, of which they may be the southern extension, and possibly the representatives of the uppermost beds of the Collie series. Mr. H. P. Woodward, during the course of an examination of this portion of the State in 1889, devoted special attention to the areas at Fly Brook, which had been taken up as coal mining leases. This observer, in a report published in 1890, stated that though there was not sufficient evidence to determine the exact age of the strata containing the Fly Brook seams, he considered it to be Mesozoic, and noted that the coals appeared to be identical in composition with the cretaceous coals of the Pacific Coast of North America.

A very large development of sedimentary rocks occurs to the eastward of Donnybrook in the neighbourhood of Collie and Wilga, which contains a store of mineral wealth in its coal measures. As a result of the mining operations which have already been carried out, much valuable geological data has been obtained, and which has thrown considerable light upon what may be called the anatomy of the district.

In answer to queries by the Royal Commissioners on the Collie Coal Industry, put to me in 1914, as will be found in that report, it was pointed out that there was no definite proof that the Donnybrook sedimentaries formed part of those occurring at Collie, though there seemed to be sound reasons for believing that such a connection would ultimately be established.

The synchronism of the Collie-Wilga beds with those of Donnybrook is, so far as the facts now go, fairly well established, and implies that they all form part of a single geological formation. The proof of this connection rests almost entirely upon considerations involving an interpretation of the lithological peculiarities of the beds, their architecture, and stratigraphy, in addition to their physiography and diastrophic history.

The Collie-Wilga beds appear as basins resulting from a widespread system of regional block faulting, and had at one time a wider extension.

The beds of the Collie Field lie at an altitude of about 600-700 feet above sea level in a depression near the north-western edge of the tableland of granitic gneiss and allied crystalline rocks, drained by the Collie River and its tributaries. The strata consist of alterations of micaceous shales, cross-bedded sandstones, and grits, with which are three well defined zones of coal measures amounting to an aggregate of over 140 feet. These latter furnish

the entire coal output of the State, and their importance can be gauged from the fact that they have up to the end of 1938 contributed 13,877,292 tons, valued at £9,142,734.

So far as can be judged from such data as is at present available, the strata have a thickness of more than 2,000 feet.

The boundaries of the coal-bearing beds are almost everywhere defined by faults to the existence of which the basin owes its preservation. The boundary fault on the south-western side of the field has been estimated to have a downthrow to the north-east of at least 2,000 feet. The effect of this block-faulting, and the incoherence of the rocks, has determined the direction of the river in that portion of the valley in which the coalfield lies.

The dip of the strata is, on the whole, fairly uniform, the inclination nowhere exceeding 12 degrees, and is in a general southerly direction.

Despite the fact that the field is traversed by many major faults, the strata have not been subjected to any serious disturbance and have suffered little or no lateral pressure.

Three well-defined productive series of coal measures have been recognised in the Collie field. The lowest certain observers have assigned to the Lower Permian, whilst the middle and uppermost groups have been relegated to the Upper Permian Epoch. The base of the beds in the area has been met with in several localities.

The sandstones of the Collie basin are distinctly crossbedded, and on examination were found to contain garnets, quartz and felspar, minerals in all probability derived from the disintegration of the crystalline and metamorphic rocks upon which they rest and which everywhere surround the field.

The rocks from which fragments of the leaves of plants had been obtained were somewhat bituminous shales, which in all probability resemble forms intermediate between coals and shales. Owing to the conditions of deposition, the coals vary in character, and in places pass insensibly through forms containing earthy matter to carbonaceous shales. The absence of underclay or "seat earth" suggests that the coal seams are in all probability of clastic origin, having been laid down on the floors of lakes or swamps of relatively moderate depth under physical conditions in which differences in climate also played a part. Such conditions would furnish an explanation of the varying percentage of ash in the seams, and also the fact that the coals of Collie possessed properties which differentiated them from others in the Commonwealth.

A somewhat important geological discovery was made during the year 1920 at Collie in a deep bore put down on the Municipal Water Reserve in the township, to a depth of 1,135 feet; this at the time being one of the deepest boreholes in the basin. The borehole passed through alternations of sandstones, shales and 17 seams of coal, one being nine feet six inches thick, and two bands of sandy limestone at depths of 1,083 and 1,133 feet respectively. This discovery of limestone—the first so far encountered—indicates a change from brackish water to estuarine or marine conditions in the Collie basin. This basal limestone, which was penetrated for two feet four inches, without reaching the base of the formation, contained calcite, quartz, felspar, kaolin, ilmenite, rutile, and some organic matter.

The coal-bearing area of Wilga lies on the fairly flat ground between the headquarters of the Preston and Collie Rivers, and is situated about $5\frac{1}{2}$ miles to the north-east of Wilga Siding at about 300 feet above the level of the Collie field.

Though a brief report on Wilga had been made by Mr. T. Blatchford in the year 1918, in which he stated that it was probably a geological replica of the Collie field, the first detailed account of the coalfield, was that given by Mr. R. C. Wilson in 1921. This report placed before geologists a fairly comprehensive statement of the constitution, structure, nature and distribution of the coalseams, and has served as the basis of all subsequent descriptions. The maps and sections showing the relation of the Collie to the Wilga field make it quite clear that the two areas were at one period coterminous and formed part of a more extensive coal-bearing area of identical geological age.

Like its neighbour, Collie, the Wilga field owes its position to having been faulted down into a trough in the ancient crystalline rocks in such a manner as to secure its protection from erosion. The longer axis of the basin, estimated to cover an area of about 24 square miles, is approximately north-west and has a general parallelism with that of the Collie River, and the fault line, which constitutes the south-western boundary of Collie.

Owing to the structural configuration of the area, and the mantle of more recent superficial accumulations, few natural sections are visible, hence an underground survey of the field was inaugurated by means of a scheme of reconnaissance boring.

The greatest depth reached in one of the four deep vertical boreholes was 691 feet, and the shallowest 550 feet 6 inches. The information furnished by these operations added considerably to our knowledge of the constitution and structure of the Wilga field, and supplied data which it was not possible to acquire in any other way. An examination of the material obtained during the course of the boring operations showed that in the lower portions of the north-eastern margin of the basin the beds below the coal-bearing horizon gradually gave place to mudstone, limestone, and boulder conglomerate.

A thin band of impure limestone was met with in No. 1 deep bore at 530 feet, beneath which, at 548 feet, was a conglomerate, assumed to be the base of the coal measures. The component fragments in the conglomerate were granite, ironstone, quartz, quartz diabase, and epidiorite. No trace of any organic remains, whether calcareous algae, glauconite, foraminifera or shells, were found in the conglomerate. Another deep bore (No. 2) carried down to 1,550 feet below the surface, entered a quartz conglomerate at the bottom, made up of pebbles of decomposed greenstone of a similar petrological character to that in No. 1 bore. No. 3 deep bore encountered a conglomerate of granite boulders, 11 feet thick, at 596 feet, resting upon granite, which was penetrated for 12 inches.

The stratigraphical information disclosed by these boring operations showed that the group of Wilga coal seams overlies the marine strata at the base of the series, and that in all probability they are on the same geological horizon as the lowest of the group of coals worked at Collie.

No fossils have, up to the present, been recorded from the Wilga area.

IGNEOUS ACTIVITY.

A striking feature in connection with the geology of the area occupied by the Donnybrook Sandstone Formation is the manifestation of igneous activity, chiefly of a basaltic nature, following or accompanying extensive earth movements.

This vulcanic activity, which has played an important part in the geological history of the south-western portion of the State, appears to have been first referred to by Mr. F. T. Gregory in 1861.

The evidences of this activity have been shown to extend from Bunbury to the south coast, a distance of about 80 miles, having a width stated to be some 12 miles, thus covering an area of not less than 1,000 square miles. This volcanic belt trends in a general north and south direction, parallel to and about six miles to the westward of the Darling Fault Scarp and its southern extension. Owing to the wide area over which these basaltic rocks are scattered, they leave little doubt that the volcanic activity must have been of no small magnitude. These igneous rocks did not, however, succeed in reaching the surface in the more immediate vicinity of the area, near Donnybrook, Collie and Wilga, though there seems to be but little doubt that the igneous magma must have been burrowing about at some distance underground.

No direct evidence as to the geological age of this igneous activity being at present available, such must in the present state of our knowledge be a matter of inference only.

A description of some of the igneous rocks occurring in the Warren River District has been given by Mr. R. A. Farquharson in the Petrological Appendix II. to the report of Mr. H. P. Woodward on "The Reputed Petroliferous Area of the Warren River," issued in 1915.

The prevalent petrographical type of these basic igneous rocks has been exhaustively dealt with by Dr. Edwards in the papers read before the Society and published in two recent numbers of its Journal, and need no further elaboration.

From the point of view of correlation, the chemical and mineralogical composition of this type of basaltic rocks given by Dr. Edwards and hitherto unrecorded in this portion of Western Australia has considerable significance, as will be pointed out later. For precise information as to the age of these volcanic rocks, some reliance has to be paid to the nature of the evidence afforded by a study of those differential subsidences which have affected the south-west portion of the State. The tectonic disturbances resulted, *inter alia,* in the formation of that modified rift valley, of which evidence is available over a wide extent of country between the south coast and that to the northward of the Irwin and Murchison Rivers, and of which the block faulting in the Collie-Wilga area form a part. The extent of this earth movement is graphically depicted on the plan showing the main faults, fault scarps, etc., which forms Fig. 38, of the last edition of the work by Mr. Jutson on "The Physiography (Geomorphology) of Western Australia," published as Bulletin 95 of the Geological Survey.

The correlation of these dislocations can, however, in the present state of knowledge only be arrived at in a very general way. These differential subsidences along the lines parallel to that of the general trend of the

dominant structural features of the district produce in the aggregate very considerable effects. The movements, however, are by no means at an end, and are of such a nature as careful seismological observations carried out over long periods of time alone can detect. The evidences of vulcanicity in association with these lines of fracture are not without their significance and practical interest.

The relationship of the basalt in the neighbourhood of Bunbury, renders it necessary to give its occurrence more than a mere passing notice, as the deductions which directly follow have important scientific and economic bearings. The earliest reference to the basalt at Bunbury would appear to be that in the paper of Mr. F. T. Gregory on "The Geology of a Portion of Western Australia," read before the Geological Society in 1861, and printed in Vol. XVI. of the Quarterly Journal of the Society. This author stated that it was a rudely columnar basalt, and that there was "no rock seen in contact with it;" in addition, the fact was recorded that the basaltic rock appeared about five miles to the south, and after crossing the Capel River outcropped on the south coast eastwards of Flinders Bay.

Mr. H. Lyell Brown, in a report (illustrated by a sketch map and section) printed under the authority of the Legislative Council in 1873, referred briefly to the basalt at Bunbury and pointed out that it was overlaid by limestone and sand. A plan and section of the basalt occurring at Cape Beaufort (Black Head) on the south coast, was also included in the report. Eleven years later (1884), Mr. E. T. Hardman described the basaltic rock at Bunbury as being an eruptive mass, which he could not trace inland. This observer, however, points out in the same report that basalt was found on the north side of the Preston River, resting upon vertical beds of granitic gneiss. The report also states that the basalt, having undergone considerable denudation, it occurred chiefly in patches, spread over an area four miles eastward, half a mile south, and two miles north-west and south-east.

Mr. H. P. Woodward, reporting on his geological investigations carried out in the country between Perth and Bunbury during 1889, that at the latter township "a dyke of columnar basalt outcrops on the beach," a statement implying that the rock had been thrust between the rocks as an intrusive sheet.

The boring operations and other collateral investigations carried out within the Municipality of Bunbury and its environs in connection with the underground water supply, have shown quite clearly that the basalt outcropping on the beach (the base of which was not exposed in any coastal section) occurs as a more or less horizontal sheet. The thickness of the basalt, as disclosed by the boring operations, proved to be very variable, owing probably to the erosion it appears to have undergone. The basalt met with at no great depth below the ground level, in five of the boreholes, was found to vary in thickness from 31 to 97 feet, and the water-bearing rocks underlying it showed no hardening or other signs of contact alteration. The bores put down in close proximity to Stirling street, which runs generally east and west from the coast to the mouth of Meredith Creek at its junction with the entrance to Leschenault Inlet, failed to reach the basalt disclosed in the northern group of boreholes. The deepest, Meredith Creek bore (or bore No. 3 as described in the Annual Report of the Geological Survey for 1897), was carried down to a depth of 416 feet, through alternating beds of clay (? shales), incoherent sandstone and conglomerate. This absence of basalt

suggests that the columnar basalt exposed on the coast and in the Brewery and other bores to the north of Stirling street is merely a remnant of a much larger sheet which spread over a somewhat larger area. This sheet possibly extended to the eastward and formed part of the patches in the Preston River valley described by Mr. Hardman, and indicates that the basalt was poured out on the surface as a lava flow, rather than being of an intrusive character.

Mr. A. Montgomery, in the account (p. 97) of his investigations in connection with the prospects of discovering petroleum in the Warren River district during 1903 on the south coast, pointed out that the sedimentary beds exposed in the rocky outcrop to the west of Black Point exhibited a twisted and crumpled stratification, due in all probability to the intrusion of a sheet of basalt between the bedding planes. On the other hand, the basalt met with in the Western Mining and Oil Corporation No. 1 bore on the Warren River was somewhat scoriaceous and represented a lava flow of a similar lithological character to that at Silver Mount.

Whether the igneous activity to which reference has been made, synchronised with that of the period of the deposition of the strata exposed in the Wilga-Collie-Donnybrook area, or represented a different stage in the geological history of the formation, does not yet appear to have been definitely established. It is, however, perfectly clear that no basaltic lava flows occur anywhere along the eastern margin of the area from Collie to the Warren River.

CORRELATION.

Consideration of the correlation of the Donnybrook Sandstone Formation with those of other regions in which the stratigraphical column has been standardised, may be approached from two distinct angles, viz., (a) that of correlation between different provinces in the same continent, and (b) that of long distant correlation between continents. These considerations differ somewhat for the two cases enumerated, for geological correlation is not only important as an end in itself, but also as a stepping stone to other things, and has in addition economic applications. Faunal and floral identity, together with the relationship to tectonic and other allied geological evidence, each have their place in endeavours to solve the problem.

An extensive search was made during the field investigations carried out in the south-west district during 1911, for any palaeontological evidence with which to assist at arriving at the position of the series in the stratigraphical column. Owing to the configuration of the country, much of the area being covered with a mantle of superficial deposits, and few natural sections visible, rendered the search for fossils difficult, and with the single exception of a very imperfect mollusc (?) from the sandstone in the Government Quarry about three miles to the north of Donnybrook, none were found. In the year 1938, however, Dr. Curt Teichert, the research palaeontologist in the University of Western Australia, discovered fossil footprints of an unidentified quadruped about the size of a dog in a sandstone from the Donnybrook district. The conditions under which the Donnybrook beds were laid down, being such as would enable vertebrates to move about freely, thus render it probable that more intensive search than has hitherto been found possible will result in further discoveries.

Consideration of the problem of endeavouring to ascertain whether a geological synchronism of the Donnybrook Sandstone Formation can be established between it and others in the Australian continent, several outstanding facts are available. It is unnecessary to give in detail a general account of such formations, for they are well known and have been fully described by other observers; attention will, therefore, only be directed to their salient stratigraphical, tectonic and other significant features.

Australia.—A considerable development of sandstones, grits, shales and thin beds of conglomerate, of freshwater or estuarine origin occurs in New South Wales, and is referred to as the Hawkesbury Series. In no other part of the mainland of Australia is this formation so widely spread as in New South Wales. Such observations as have been made on it, together with the completeness and variety of the series, its petrographical constitution, as well as its fossil fauna and flora, give it considerable importance in comparative geology. The formation is also of considerable thickness, for the base of the series in the neighbourhood of Sydney is nearly 3,000 feet below sea level. The Hawkesbury Series has been intruded by basalt (dolerite) dykes, though no evidence of surface lava flows appears to have been recorded. The available palaeontological evidence indicates a Triassic Age for the series. The Donnybrook Sandstone Formation bears a close resemblance to the Hawkesbury Series, of which it may be the equivalent. Small quantities of gold occur in some of the sandstones of the Hawkesbury Series, and it is probably more than a coincidence that gold of secondary origin has been recorded by Messrs. Blatchford and Forman in one of the sandy beds of the Donnybrook Sandstone Formation. In this connection it may be pointed out that some types of mineral deposits appear to be connected with igneous activity, which either supplied the heat and vapours, or set auriferous solutions in circulation.

A formation which in many important respects resembles that of the Hawkesbury Series of New South Wales, of which it is believed to be of the same geological age, covers a fairly extensive area in the central, south-eastern and eastern districts of the island of Tasmania. The strata estimated to be over 1,200 feet thick, and of freshwater or estuarine origin, consist largely of sandstones, associated with coal seams, the most important in the State. The beds contain a fossil flora which clearly link them with the Hawkesbury Series; in addition, a single bone of a fossil reptile, stated to belong to the order Cotylosauria, has been recorded from the rocks near Hobart, indicating a lower Triassic Age for the formation. The strata of this age in Tasmania are marked by the intrusion of dolerites, in the form of laccolites, sills sometimes 2,000 feet thick, and dykes to an extent which differentiates them from equivalent strata on the mainland. These evidences of vulcanicity marked the close of the Triassic Period in Tasmania. These intrusions were associated with such earth movements as gave this geological era in Tasmania several features of individuality. The doleritic intrusions which intersect the Tasmanian Coal Measures find their analogue in the Karoo beds of South Africa, where evidences of a stupendous outburst of vulcanic energy are so pronounced. The tabulated analysis of the Karoo dolerites by E. Cohen bear a resemblance to those from south-western division of Western Australia by Dr. Edwards. Their congenetic nature is indicated by general similarity in chemical and mineralogical composition, and implies that they form part of a single petrographical province.

An assemblage of lacustrine strata, at least 2,000 feet thick, containing low-grade coal seams, has been met with in South Australia, at Leigh's Creek, to the eastward of Lake Torrens. These beds, which are stated to lie in a faulted basin, bounded by rocks of Lower Palaeozoic Age, in many respects bear a marked stratigraphical resemblance to those at present under discussion. The Leigh's Creek beds have, on the available palaeontological evidence, been assigned to the Lower Mesozoic (Triassic) Period. There are other areas in South Australia in which strata, inferentially of the same age, have been met with in the course of boring operations, thus indicating a fairly wide extension of this formation.

SOUTH AFRICA. The marked stratigraphical and tectonic parallelism between Western Australia and that of South Africa, and the other countries bordering the southern portion of the Indian Ocean, has often been made the subject of scientific remark. It is significant to note that the fossil remains of a carrion-eating reptile—*Gomphognathus*—about the size of a large dog, has been found in the upper portion of the Beaufort (Triassic?) Beds, which were originally named the "Republican Beds." This, however, while suggestive, can hardly be taken as definite evidence that the deposits in the two continents are of equivalent age. The Beaufort Beds bear a marked stratigraphical resemblance to the strata occurring in the extreme south-western division of this State. The Beaufort Beds of South Africa contain, in addition to the fossil vertebrates, by which the series is characterised, representatives of the Glossopteris flora, examples of which have been met with in the strata of the Collie Coalfield in Western Australia. The Donnybrook Sandstone Series is non-marine in origin, and there appear to be sound geological reasons for regarding it as representing some portion of the Karoo system as typically developed in and extending over such a large area of South Africa, and the equivalent Gondwana system of India. However, until further fossils are discovered in Western Australia, confirmation of this view must remain somewhat a matter of conjecture. The environment under which the beds were deposited is not only of considerable scientific interest, but has important economic applications by virtue of the occurrence of coal seams, as well as its hydrological aspects. The Karoo System, a widespread formation of continental origin, forms a laterite capped peneplain, now undergoing dissection, contains what is practically an unbroken chain of vertebrate life, ranging from Middle Permian to the close of Triassic time, and the land plants, as well as coal seams, of the Mesozoic Continent of Gondwanaland.

There are scientific reasons for believing that what is now Western Australia formed a remote corner of this ancient continent which linked Africa—structurally the most stable of all the continents—and the countries bordering the Indian Ocean, *i.e.,* Madagascar, India, etc.

A great revolution in physical geography resulted in the dismemberment of Gondwanaland, and produced, *inter alia,* the present continent of Australia, by virtue of what has generally been described as the Wegener Drift hypothesis. This is based on the assumption that the continents are merely broken fragments of a great sheet of lighter and more acid rock floating upon a denser one of more basic composition. This, however, does not necessarily imply that the present shore lines were absolutely adjacent, but that they were very much closer at different periods of geological history, and have always maintained a more or less general parallelism. The con-

ception also implies that these fragments may still be wandering laterally: that such is the case may be inferred from the results of a comparison of the determinations of longitude made between the years 1823, 1870, and 1932, from which it was shown that Sabine Island, in East Greenland, had moved some considerable distance to the westward. Recent researches, however, indicate that such lateral wandering could also have resulted from a differential vertical and subsidence of crustal blocks, due to a shrinking of the earth's crust. The exact explanation of this continental wandering is not yet quite clear, though it may, as the matter becomes more closely investigated, be found to have resulted from a combination of both factors. However this may be, enquiry into the causes of such peregrinations is foreign to the scope of this paper. On the lines of Wegener's speculations and collateral results, it is to the westward that those great connections which help to explain the many problems of the past and present geological history of Western Australia will have to be looked for.

In view of the marked structural, stratigraphical and palaeontological resemblance of the western portion of the Australian continent, to that of India, South Africa, and Madagascar, as exhibited in all the formations from the Archaean to the Recent epoch, it is important to consider the bearings which such have upon the matter of the intercontinental relationships of the Donnybrook Sandstone Formation.

A careful study of the latest geological maps of South Africa, India and Australia is of special value in any endeavour to reassemble the broken fragments of Gondwanaland, which in view of its wanderings must originally have had a very much smaller area than has been usually pictured. Attempts have been made by some to replace the Australian continent in the position it inferentially occupied in relation to the stable mass of Africa, by the suggestion that Australia and New Guinea, along with its island satellites, had drifted away to the eastward from what is now the Arabian Sea. This view, however, on account of the dissimilarity of the geological constitution and grain of the countries bordering the Arabian Sea, hardly seems feasible. Another view of this reconstruction inclines to the belief that the eastern coastline of Madagascar, which has a general parallelism to that of the South African coast, was in intimate connection with Peninsular India on its western flank. If as part of this suggested continental union, Australia originally occupied a portion to the southward of Madagascar, it would furnish an explanation of the marked concordance not only in the geological structure but also the grain and other stratigraphical characteristics. A feature of some significance in this connection is the dominant east-west strike of the trend lines of the folding exhibited in the older rocks of the southern corner of Africa, and that represented by the Stirling Range-Mount Barren beds. Of these the eastern extension probably lies beneath the Great Australian Bight in close association with the depression, the Jeffrey Deep of the Admiralty Charts and thence through Kangaroo Island to Eyre's Peninsula in South Australia.

SUMMARY.

Whenever an answer to the question as to the precise geological age of the Donnybrook Sandstone Formation is received, it will, in probability, be found to have resulted from a combination of palaeontological and other recognised stratigraphical researches. As its name suggests, this group, which

covers a wide extent of country in the south-west corner of the State, consists chiefly of sandstones, alternating with shales and coal seams of workable thickness, together with thin layers of more or less impure limestones. Regional block-faulting has affected the formation, and has been responsible for the preservation of the mineral wealth in its coal measures, the annual production of which, furnished the entire coal output of Western Australia. In intimate association with these beds is a large development of basaltic rocks of the precise age of which there is at present no direct geological evidence. The base of the Donnybrook Sandstone Formation has not been seen, though it has been met with in the course of boring operations at depths which vary from 500 to 1,130 feet from the surface. Few fossils, the guiding stars of sedimentary geologists, have been met with in this strata, whilst the number of identifiable plant remains hitherto recorded from the formation is comparatively small, and appears to be insufficient to warrant discussion of its relationship to the faunas elsewhere. In the absence therefore of detailed palaeontological evidence, determination of the geological age of the formation is mainly dependent upon a correlation of petrological characters, structural peculiarities, community of origin, tectonic relationships, and the results of other cognate activities.

Whenever the obscurities which at present envelope the problem are considered it seems quite clear that further sympathetic co-operation, both in the field, the study, and the laboratory will be required to establish beyond doubt the geological epoch to which the Donnybrook Sandstone Formation and its associates belong.

CONCLUSION.

After giving due weight to all the considerations involved, it would seem that evidence for a Triassic Age of the Donnybrook Sandstone and its associates can be discerned. Such has, with a measure of confidence in striking contrast to the, as yet circumstantial data, strong claims to acceptance as a working hypothesis, bearing clearly in mind that "Pioneer Geology has to choose between the rashness of using imperfect evidence, or the sterility of uncorrelated and unexplained facts."

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CONTRIBUTIONS TO THE FAUNA OF ROTTNEST ISLAND.

11.—PYCNOGONIDA OF WESTERN AUSTRALIA.

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INTRODUCTION.

The Pycnogonida whose examination forms the basis of the present paper were collected at Rottnest on the West Australian coast by Mr. L. Glauert, Curator of the West Australian Museum.

The whole collection, with the exception of three individuals, is made up of specimens of *Ammothella bi-unguiculata,* the first members of the genus *Ammothella* recorded as occurring in Australasian waters. Of the three exceptions, two form a new variety of *Nymphopsis acinacispinatus* (Williams), the holotype of which was secured from the Queensland coast, whilst the remaining specimen is referable to Loman's relatively new genus *Pycnothea* (Loman 1922).

Ammothella bi-unguiculata (Dohrn) has now been recorded from such widely separated regions as the Gulf of Naples, the Californian coast, and finally, the West Australian coast. Although the present variety is uniformly larger, it nevertheless bears a close resemblance to the holotype described by Dohrn from the Gulf of Naples.

The genotype *Pycnothea selkirkii* was obtained by the Swedish Expedition to Juan Fernandez and described by Loman in 1922. *P. flynni* is thus the second species of the genus to be recorded.

My thanks are due to Professor T. Thomson Flynn for the opportunity of studying this collection and for much helpful criticism.

Ammothella bi-unguiculata, var. **australiensis**, var. nov.

DESCRIPTION.

Trunk. Fairly stout. Lateral processes separated by about half their own diameter. Segmentation distinct. In a few specimens the most posterior suture is not well marked. Cephalic segment sub-equal in length to the second and third segments taken together. Cephalon fairly broad and swollen dorsally. Ocular tubercle low, wider than high, bluntly rounded anteriorly and flattened apically. Four well-marked equally developed eyes. Proboscis of very long elliptical shape, slightly longer than trunk, widest in the middle. Abdomen short, projecting upward at an angle of 45°.

Chelophores. Very minute, chela less than half as long as scape and rudimentary. Scape two-jointed although proximal joint appears to be fused to the cephalon.

Palps. Longer than proboscis, nine-jointed. First segment short, second and fourth segments sub-equal, third, fifth and sixth joints approximately equal. Well developed ventral extensions occur on four distal segments, each of which bears many clusters of sensory hairs.

Origers. Ten-jointed; proportionate length of segments different in male and female. Male—terminal joints swollen and short; two pinnate spines borne by tenth segment, whilst seventh bears a tuft of five long stiff spines. Female—paired pinnate spines borne on seventh, eighth and tenth segments. A single strongly curved spine near the distal extremity of segment nine is very characteristic of both sexes.

Legs. Fairly stout; all joints bear scattered spines. Second coxa more than twice as long as first and longer than third. First tibia two thirds length of second tibia; femur slightly shorter than the latter. Tarsus very small, bears tuft of spines ventrally. Auxiliary claws curved and well-developed being a little more than one quarter the length of propodus. Main claw vestigial. Spines numerous on ventral surface of propodus and at its extremity.

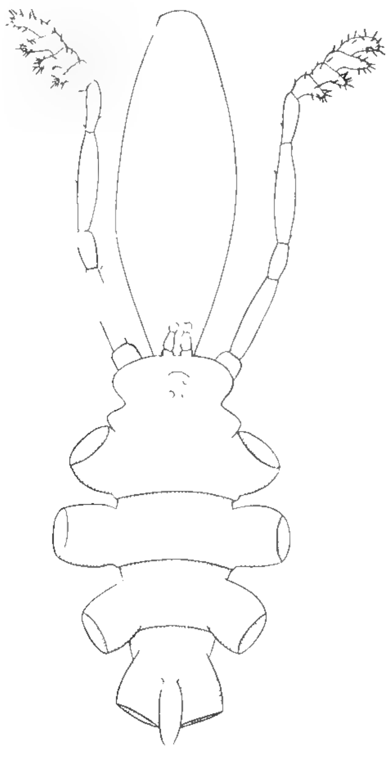

Figure 1.—Ammothella bi-unguiculata, var. australiensis, n. var., male. Dorsal view of body with palps and rudimentary chelophores. (x 25)

MEASUREMENTS OF MALE (HOLOTYPE) IN MM.

Length of Proboscis	1.4
Length of Cephalic Segment	0.63
Total length of Trunk	1.5
Greatest width of Cephalic Segment at the level of the 1st pair of lateral processes	0.87
Width of Trunk between the 1st and 2nd pairs of lateral processes	0.35
Length of Abdomen	0.37
Length of Chelophores	0.17

Third right leg:—

First coxa	0.23
Second coxa	0.513
Third coxa	0.41
Femur	0.78
First tibia	0.725
Second tibia	1.07
Tarsus	0.08
Propodus	0.46
Length of auxiliary claws	0.145

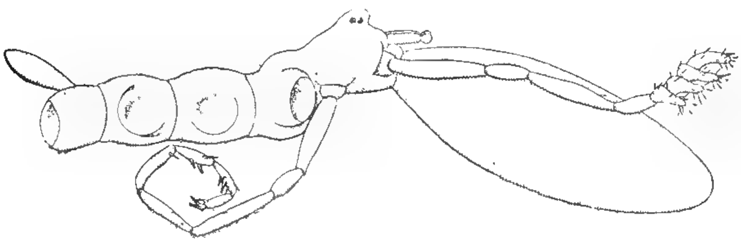

Figure 2.—Ammothella bi-unguiculata, var. australiensis, n. var., holotype female. Lateral view of body with palps, right oviger and rudimentary chelophores. (x 22)

MEASUREMENTS OF FEMALE (HOLOTYPE) IN MM.

Length of Proboscis	1.62
Length of Cephalic Segment	0.72
Greatest width of Cephalic Segment at the level of the 1st pair of lateral processes	1.07
Width of Trunk between 1st and 2nd pairs of lateral processes	0.4
Total length of Trunk	1.68
Length of Abdomen	0.46
Length of Chelophores	0.202

Third right leg:—

First coxa	0.23
Second coxa	0.522
Third coxa	0.44
Femur	0.89
First tibia	0.84
Second tibia	1.16
Tarsus	0.116
Propodus	0.551
Length of auxiliary claws	0.14

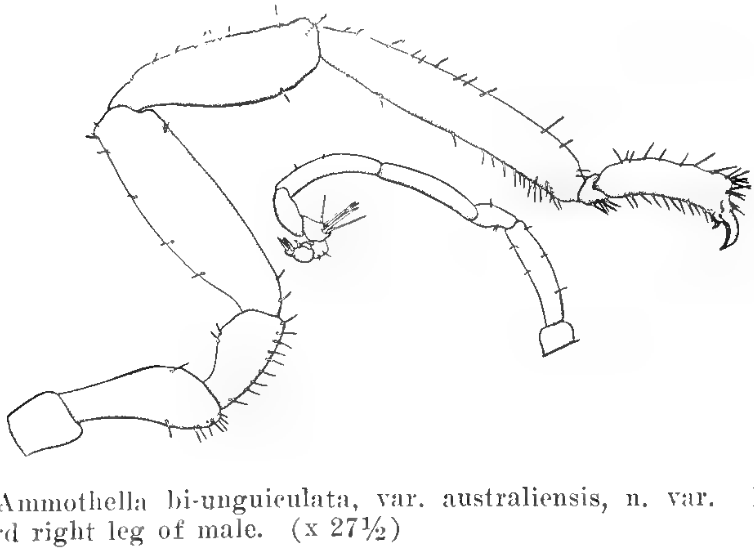

Figure 3.—Ammothella bi-unguiculata, var. australiensis, n. var. Right oviger and third right leg of male. (x 27½)

REMARKS.

The holotype of *Ammothella bi-unguiculata* was described as *Ammothea bi-unguiculata* by Dohrn (1881) from an immature specimen taken in the Gulf of Naples. It was Cole (1904) who referred this specimen to Verrils genus *Ammothella*. There are two varieties of this species now known. The first of these, *Ammothella bi-unguiculata* var. *californica*, was described by Hall in 1912 and came from Laguna on the Californian coast. It differed in no essential from the holotype and only the extreme distance between the localities can be said to justify, if at all, the retention of *Ammothella bi-unguiculata*, var. *californica* as a distinct variety.

The variety *australiensis* here described, whilst closely resembling the holotype in many ways, can be distinguished by the difference in shape of the anterior part of the cephalon, the reduction in the number of joints in the scape of the chelophores, and by the distinctly serratiform nature of the four terminal joints of the palp. Unfortunately, as to this point, the condition of the terminal segments of the palp cannot be ascertained from the figures either of Dohrn or Hall. Neither alludes to serratiform outgrowths. The three varieties, that is, the holotype, the Californian and the Australian, all show the same peculiar suppression of the main claw and the great development of the curved auxiliary claws.

Bouvier 1913 has abandoned the opinion that *Ammothella* should be considered as a distinct genus and is, I believe, on right lines in suggesting that with *Ammothea* (*Leionymphon*) and *Achelia* it should rank as a subgenus of the genus *Ammothea*. Diagnoses of these subgenera are given by Bouvier.

Certain forms do occur, however, which combine some of the characters of more than one subgenus, thus *Achelia uni-unguiculata* (Dohrn) has a scape of two joints, normally characteristic of the subgenus *Ammothella*. Similarly, in *Achelia hispida* (Hodge), the palp is made up of nine joints, instead of the characteristic eight. On the whole, the more normal members of the subgenus *Ammothella* would appear to be more closely allied to the subgenus *Ammothea*. The difference in the condition of the scape, although very characteristic in some, is not so distinctive in others, for in the latter the proximal joint of the scape, besides being small, is fused to the cephalon, with the result that the chelophore scape appears to be single-jointed although set upon a short pedestal. Such forms are nevertheless described as possessing a two-jointed scape and in all probability they represent a transitional stage between species in which the scape of the chelophore is two-jointed and species which have but a single-jointed scape. *Ammothella bi-unguiculata* var. *australiensis* represents such an intermediate form. The type is in the collection of the Western Australian Museum.

Nymphopsis acinacispinatus, var. **bathursti**, var. nov.

Occurrence—Bathurst Point, Rottnest. 2 specimens male.

Both specimens closely resemble the species of *Nymphopsis* (*N. acinacispinatus*) obtained from Port Curtis, and described in the Annals and Magazine of Natural History (Williams). The present variety, besides being uniformly smaller, differs from the Queensland specimen in the following points:—(1) The trunk is shorter than the abdomen. (2) The three dorsal compound spines and the ocular tubercle are approximately equal in height. (3) The ocular tubercle is tall and lacks the prominent pointed apex found

in the Queensland specimen. (4) The armature of the legs is different. (5) The genital process occurring on the second coxa is well developed on only the 3rd and 4th legs, being rudimentary on the 1st and 2nd.

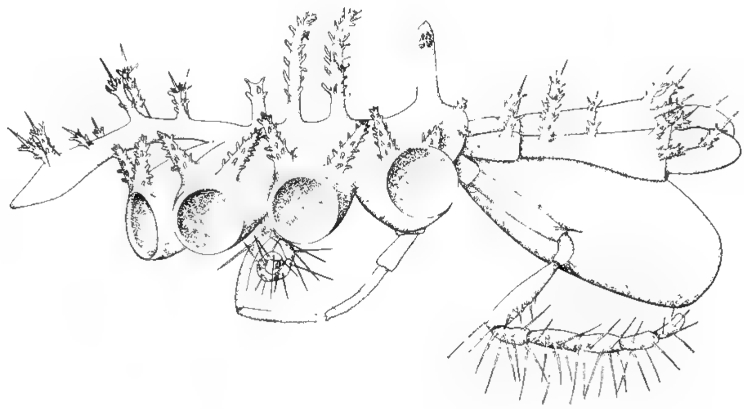

Figure 4.—Nymphopsis acinacispinatus, var. bathursti, n. var., male. Lateral view of body with chelophores, palp and oviger. (x 20)

MEASUREMENTS IN MM.

Length of Proboscis	1.6
Length of Trunk	1.1
Length of Abdomen	1.3
Length of Chelophore	1.3
Third right leg:—	
First coxa	0.4
Second coxa	0.6
Third coxa	0.43
Femur	1.25
First tibia	1.1
Second tibia	1.01
Tarsus	0.145
Propodus	0.87
Main claw	0.55
Auxiliary claws	0.27

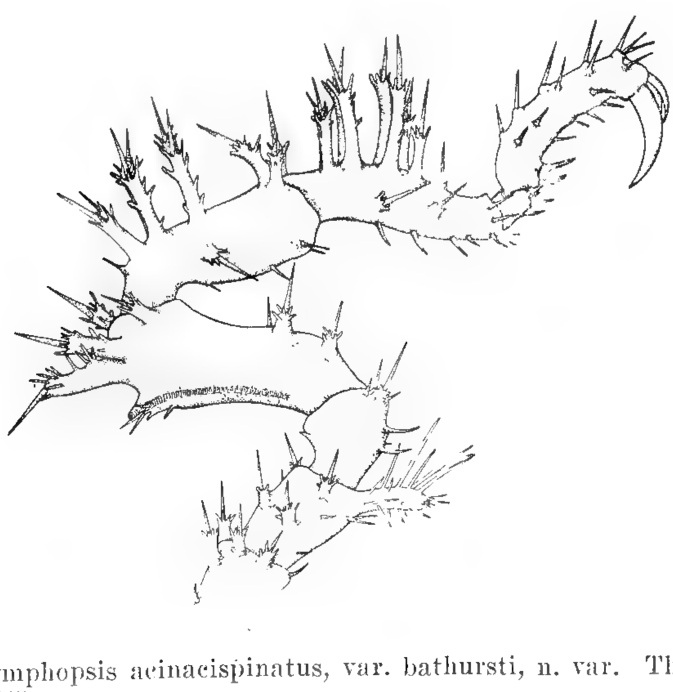

Figure 5.—Nymphopsis acinacispinatus, var. bathursti, n. var. Third right leg of male. (x 25)

The type is in the collection of the Western Australian Museum.

Pycnothea flynni sp. nov.

1 specimen, male.

DESCRIPTION.

Trunk. Stout, incompletely segmented, last two segments united. Lateral processes short and nearly touching one another. Cephalic segment considerably longer than rest of trunk, expanded anteriorly into collar which conceals the base of the proboscis and the bases of the chelophores. Low, rounded, dorsal elevations occur opposite the first and second pairs of lateral processes; each is beset with a loose tuft of short hair-like spines. Ocular tubercle low, stout and with a flattened apex, situated just in front of first lateral process, near posterior margin of collar. Eyes well-marked and approximately equal. Proboscis slightly shorter than cephalic segment, narrower at tip than at base. Abdomen short and stumpy, swollen in middle and carried horizontally.

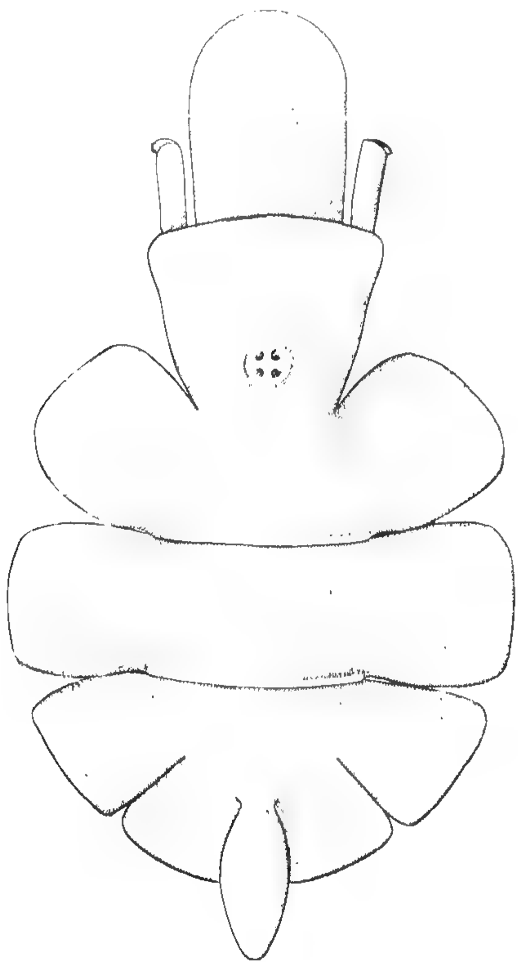

Figure 6.—Pycnothea flynni, sp. n., holotype male. Dorsal view of body with chelophores. (x 25)

Chelophores. Very small and widely separated. Scape of chelophore one-jointed. Chelae with well-developed equal untoothed fingers.

Palps. Absent.

Ovigers. Ten-jointed, first and second joints almost twice as thick as remaining joints; third, fourth and fifth sub-equal, remaining joints small, tenth smallest. Terminal joints bear scattered spines. No end claw.

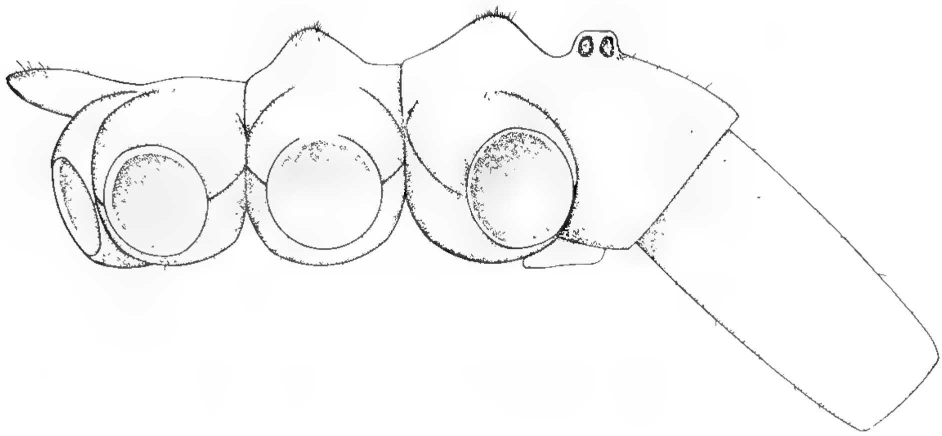

Figure 7.—Pycnothea flynni, sp. n., holotype male. Lateral view of body. (x 25)

Legs. With short coxae; second coxa longest, bearing the male genital process, a thick ventro-distal off-shoot on the third and fourth legs. Femur and second tibia sub-equal, first tibia slightly shorter. Tarsus small. Propodus two thirds length of second tibia. Main claw half length of propodus; auxiliary claws half length of main claw. Numerous short spines occur on all joints.

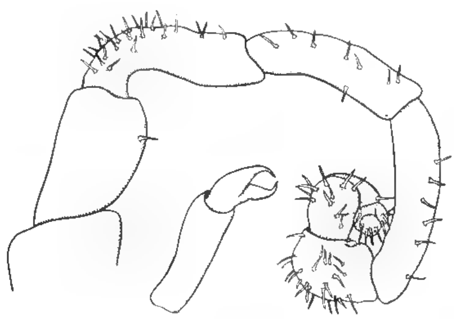

Figure 8.—Pycnothea flynni, sp. n., holotype male. Right chelophore (x 22½) and oviger. (x 27½)

MEASUREMENTS IN MM.

Length of Proboscis	1.3
Length of Cephalic Segment	1.4
Length of Trunk	2.33
Width of Trunk at the level of the second pair of lateral processes	2.1
Length of Abdomen	0.666
Length of Celophores	0.62
Third right leg:—	
First coxa	0.51
Second coxa	0.75
Third coxa	0.66
Femur	1.58
First tibia	1.4
Second tibia	1.63
Tarsus	0.25
Propodus	1.14
Main claw	0.555
Auxiliary claw	0.259

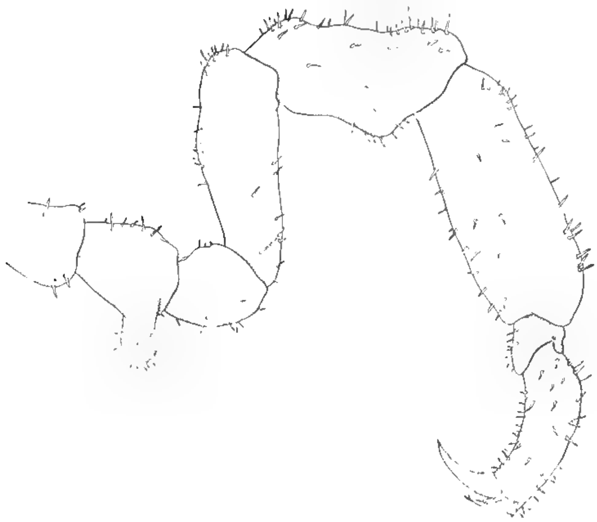

Figure 9.—Pycnothea flynni, sp. n., holotype male. Third right leg. (x 15)

REMARKS.

The present specimen agrees with Loman's genus *Pycnothea* described in his report on the Pantopoda collected by the Swedish Expedition to Juan Fernandez and Easter Island. It differs from the genotype, however, in a number of points. Thus in *P. flynni* there are two dorsal mounds on the body, relics, probably, of the body ridges so frequently present in *Ammothea*. There is no suggestion of any such outgrowths in Loman's species. Secondly, the chelophores, though quite small in *P. flynni*, are very much larger than those of *P. selkirkii*. Thirdly, the ocular tubercle is low in *P. flynni*, but is a definite pedestal, whereas in *P. selkirkii* it takes the form of a small mound. Fourthly, in *P. flynni* it occurs well in front of the lateral processes carrying the first pair of legs, whilst in *P. selkirkii* it is placed at the posterior border of the cephalic segment. Finally, the trunk in *P. flynni* is nearly twice the length of the proboscis, whereas in *P. selkirkii* the trunk is but little longer than the proboscis. The type is in the collection of the Western Australian Museum.

Note.—Just previous to publication a reference has been discovered in the Zoological Record, vol. lxv. 1928, to the occurrence of *Ammothea biunguiculata* off the coast of Japan. It has not been possible to obtain a copy of this paper "Notes on some Pycnogons living semi-parasitic on Holothurians." Ohshima, H. *Proc. Imp. Acad.* Tokyo vol. 3, 1927. pp. 610-613.

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MINERAL PROVINCES AND METALLOGENETIC EPOCHS IN WESTERN AUSTRALIA.

PRESIDENTIAL ADDRESS, 1939.

By EDWARD S. SIMPSON, D.Sc., B.E., F.A.C.I.

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INTRODUCTION.

The most superficial consideration of the distribution of metallic ores, and other commercial minerals, throughout the world discloses the fact of their very irregular and unequal distribution. A closer study of these economically valuable resources in the field reveals the further fact that any particular mineral may be found in one region only in very ancient rocks, and in another only in much more recent ones. From these observations arose the twin concepts of metalliferous provinces in the land areas of the globe, and of metallogenetic epochs in the earth's history. A logical expansion of the originally restricted idea of metalliferous provinces leads to the more general concept of mineral provinces, which embraces the distribution of non-metallic as well as metallic minerals.

A thorough understanding of the local application of both these ideas is essential to the systematic development of any country's mineral resources, and the logical planning of its future industrial expansion. Incidentally it has led to much heart burning and covetousness on the part of progressive peoples.

MINERAL PROVINCES.

Studying first in detail the idea of mineral provinces, we find that certain more or less well-defined areas of land, ranging from, say, 1,000 square miles to 100,000 or more square miles, are abnormally rich in one valuable mineral, often in several, and completely devoid of, or very poor in, many others. There appears, therefore, to be, firstly, a defined and restricted distribution in each continent of each valuable metal or mineral, and secondly, an incompatibility of occurrence between certain pairs or sets of minerals, as for example, between gold and tin, copper and coal, asbestos and lead. Such incompatibilities are, in fact, commonly observed and well established as the outcome of natural laws. They are not, however, invariable, as from time to time apparently incongruous associations are recorded. The exceptions, however, are sufficiently rare not to upset the practical application of the general law, but serve only to emphasise the complexity of all natural processes, and the imperfection of our knowledge of them. In general, the obvious natural law appears to be that if any two minerals have their own distinctive, and invariable, or almost invariable, modes of origin, and if these modes are quite different from one another, then the two minerals will not be found in commercial abundance in the same area. To anticipate somewhat a latter section of this address, exceptions to this law may usually be traced to two very different conditions prevailing in the region at two different ages of the earth's history. In certain portions of South Africa for example, two usual incompatibles, diamonds and gold, are found plentifully in one province, the explanation of which is that they were formed at different epochs under different prevailing conditions.

In contradistinction to these incompatibilities there are many well-established compatibilities of occurrence based on genetic identities. Thus regions rich in lead are very often rich also in zinc and silver, and others rich in tin are not uncommonly rich in tungsten, tantalum or lithium minerals. This arises from the fact that the members of each of these two dissimilar groups are derived in the same way by characteristic types of pneumatolytic and hydrothermal action from similar magmas. Again, provinces rich in chromite will frequently be found to be rich in platinum, or nickel or chrysotile asbestos, since all these are usually segregated *in situ* from similar ultrabasic magmas. In other provinces coal and iron carbonate ores are abundant, in others again sulphur, gypsum and petroleum, since both groups are originated by sedimentation under similar conditions in shallow restricted areas of water.

The science of economic mineralogy, building on the fundamental observations and deductions of von Cotta[1], Phillips[2], Posepny[3], Van Hise[4], Lindgren[5], and others, has now reached the stage at which a comprehensive list of the usual compatibilities and incompatibilities can be drawn up with a considerable degree of assurance. Furthermore, State and exploratory geological surveys are sufficiently advanced over large areas of the globe to enable many mineral provinces to be accurately defined.

It is of the greatest practical importance to seek to discover what causes govern the distribution of metalliferous or earthy mineral provinces, and the compatibilities and incompatibilities traceable within each of them, so as to be able to apply the results of these researches to our own State in the direction and control of the mining industry. It is here necessary to emphasise the fact that the average amount of the valuable metals and non-metallic elements in the whole of the earth's crust that is within the range of mining operations is in most cases extremely small. An actual estimate is given in Table 1, compiled from the publications of F. W. Clarke, H. S. Washington, and others[6-12]. Even the most abundant of the valuable metals aluminium, iron, potassium and magnesium are, on the average, present in amounts which would not constitute a workable deposit. And others of our common metals, such as copper, lead, zinc and tin, are in such small quantities that if evenly distributed through the crust, they would cost as much as gold to produce.

AVERAGE PROPORTIONS OF METALS, ETC., IN EARTH'S CRUST.

Aluminium ...	7·5 per cent.	Sodium ...	2·6 per cent.
Iron	4·7 ,,	Potassium ...	2·4 ,,
Calcium ...	3·4 ,,	Magnesium ...	1·9 ,,
Titanium ...	·6 ,,	Barium ...	·04 ,,
Phosphorus ...	·1 ,,	Chromium ...	·04 ,,
Manganese ...	·09 ,,	Nickel ...	·03 ,,
Carbon ...	·08 ,,	Copper ...	·01 ,, = 100 parts per million
Sulphur ...	·06 ,,		
Zinc	40 parts per million	Boron	10 ,, ,,
Cobalt	30 ,, ,,	Beryllium ...	10 ,, ,,
Lead	20 ,, ,,	Arsenic ...	10 ,, ,,
Tin	5 ,, ,,	Molybdenum ...	<1 part per million
Antimony ...	<1 part per million	Mercury ...	<1 ,, ,,
Bismuth, Tungsten, Tantalum, Niobium, Silver, Gold, Platinum			Less than 1 part in ten millions.
Radium			About 1 part in a billion.

Fortunately for the development of our civilisation, nature has been at work through the ages making local concentrations of metals and minerals that we need. And this has been done on such a scale and to such good effect that we are able to obtain without great difficulty and at reasonable expense the supplies of metals and minerals that we require. In this connection I do not intend to enter into the old, and still intermittently disputed argument, as to whether the workable concentrations of heavy metals were ultimately derived from deep-seated volcanic magmas, or from the adjacent rocks on the same horizons as the deposits themselves[3 13]. I will merely assume that this argument will ultimately be satisfied, as so many others have been, by the realisation that both causes are effective to varying degrees in various places. In the former case the medium by which the concentration is effected is the hot water and steam given off by the cooling igneous magma, and in the latter either similar agencies, or the comparatively shallow circulation of atmospheric water. For the purpose of our present argument, one must realise that the intense concentraion of an element by nature in a limited area has meant that a much larger area surrounding it has been starved of that element. This is a fact having an important bearing on the theory of mineral provinces.

There are four obvious influences, all of paramount importance, in localising commercially valuable mineral deposits. These are:

(1) The nature and origin of the immediate "country," *i.e.*, the actual enclosing rock or rocks; (2) the nature of the igneous rocks underlying and closely surrounding the rock matrix; (3) the dynamic history throughout geological time of the individual district, or province; (4) the extent to which rock formations containing valuable mineral deposits, or capable of developing them, have been overlaid by later rocks of a different, and often entirely unfavourable nature.

Let us consider in more detail these fundamental influences. Broadly speaking, workable deposits of minerals may be divided into two main classes, (1) those originating from subterranean action, including volcanic intrusion and fluid circulation, (2) those originating from surface erosion and subsequent deposition. The former fall into two groups: (A) Those derived by segregation in an original molten matrix, *e.g.*, platinum, chromite, ilmenite; (b) those derived mostly from igneous magmas, but transported elsewhere by vapours or solutions before deposition, *e.g.*, gold, cassiterite, lithium minerals, etc. Class (2), of course, embraces such well-known minerals as coal, salt, limestone, and many iron ores.

These facts profoundly influence the regional distribution of mineral deposits, for whilst minerals of Class (2) can only be found in areas occupied by sedimentary rocks, and in many cases are confined to those of certain restricted ages, minerals of subterranean origin are found not only in areas where igneous rocks outcrop, but in the case of that most important group, (1)B, in areas of all kinds of rocks, both igneous and sedimentary, though usually at a limited vertical or horizontal distance from igneous rock of some kind or other.

The influences controlling mineral deposits of igneous origin are of especial importance in Australia. They include both the gross compositional type of the igneous rocks of a district, and the variable distribution in these of traces of what are, broadly speaking, rare elements.

The members of the compatible group platinum-chromite-chrysotile asbestos-magnesite are, for example, almost without exception confined to the ultrabasic rock group, characterised by a high content of magnesia and a low content of alkalis and alumina. The elemental materials for forming the three last minerals are comparatively common constituents of all such rocks, but platinum is a "trace element" of very capricious distribution, even in its favourable matrix, and hence workable deposits are confined to a very small percentage of the known areas of ultrabasic rocks.

This variable distribution of trace elements of human value in magmas of similar type is one of the most important factors in originating and defining mineral provinces. In the original magmas from which so many commercially important concentrations of metallic and non-metallic elements are derived, most of those elements occurred only as apparently insignificant traces. The first stage in their concentration is the crystallising out of vast bulks of common rock-forming minerals, such as pyroxenes, felspars and quartz, leaving a mobile water-bearing residue much richer in the trace elements, which tends to migrate into restricted cavities which are under much less pressure and temperature.

Dissimilar magmas, *e.g.*, those of doleritic and granitic types, differ not only in their major constituents by which they are grouped, but undoubtedly also in the nature and proportion of their trace elements. Further, even otherwise closely similar magmas differ enormously, in different regions, in their content of these valuable traces. Thus it is a reasonable deduction from observed facts that, of many otherwise identical granites, those which are relatively rich in gold, tin, lead or radium are of very restricted distribution. The same may be said of those dolerites and syenites from which important concentrations of gold, silver or copper have been derived; or of those peridotites which have yielded valuable amounts of nickel or platinum. An important step, therefore, in the definition of the metalliferous provinces of any region is the tracing of the boundaries of favourable magmatic intrusions, and this is usually recognised as a fundamental function of official geological surveys.

Fortunately certain intrusive rocks, in restricted areas, contain several times the average proportion, and even, in rare instances, several hundred times this proportion of one or more valuable elements. This is the ultimate basis of many of our metallic provinces.

So far I have only dealt in detail with the second of my suggested fundamental influences. Let us now deal briefly with the first, viz., the nature of the immediate country of certain mineral deposits. I have already referred to its paramount importance in the case of those minerals characteristic only of ultrabasic rocks. Assuming that the elements of certain minerals occurred originally in fluid effluents from igneous magmas, these vapours or solutions would preserve their stability and form no useful deposit unless their equilibrium is upset by changing physical and chemical conditions. Physical changes include reduction of temperature and pressure, which are found in the channels of migration, but are seldom in themselves sufficient to completely serve our purpose, but chemical interaction with the walls of the cavities through which the fluids are moving, and with solutions of different origin seeping into them, is capable of producing heavy precipitation. Thus it is very probable that tin and tantalum migrate from granite magmas in solutions in which they are in equilibrium with fluorine, and

which are stabilised by excess of hydrofluoric acid. Such solutions are completely altered by contact at lower temperatures with reactive compounds of alumina and lime, which interact with the fluorine radicle, and allow the tin to hydrolyse to tin oxide (cassiterite), and the tantalum in the presence of available iron, manganese or yttrium to form stable compounds with those metals devoid of fluorine.

Again, gold appears to arise in many instances from a magma as a sulphaurate ion in equilibrium with potassium in a neutral or alkaline solution. Such solutions are most readily affected by certain iron compounds such as ferruginous chlorites, magnetite and haematite, the result being the simultaneous precipitation of pyrite or pyrrhotite and metallic gold. Quite frequently the original magmatic solutions include the sulpharsenite ion, in which case the same causes produce a precipitation of metallic gold and arsenopyrite, the latter the most important source of commercial arsenic.

Again inverting the order of my original postulates, my fourth fundamental influence was the burial of mineral bearing formations with later ones of sedimentary or volcanic origin. Where this burial is not too deep, *e.g.*, in the case of the auriferous deep leads of Victoria, which have been buried beneath barren flows of basalt, it has often been found possible to deduce the existence of possibly payable ore beneath the later cover and to mine it economically. In the case of petroleum this burial of the valuable strata is essential to the preservation of oil supplies through geological ages for our present use, and by boring on systematic lines the oil reservoirs are located and controlled within bounds during commercial exploitation. Coal, rock salt, potash salts and boron salts are further instances where the preservation by geological burial has been of the greatest value to mankind.

On the other hand there are many instances where metalliferous rocks have been traced up to the boundaries of an old formation, and then completely lost beneath a thick series of more recent barren sediments, thus seriously restricting a metalliferous province. Many instances of this will recur to you in our own State, especially in regard to our main gold province.

The last of my fundamental influences is that of the dynamic history of the region under consideration, which leads us to the second section of my address viz., that dealing with metallogenetic epochs. It is obvious that if the vapours and solutions containing valuable elements are to migrate and be precipitated for our benefit in concentrated form, there must be cavities, *i.e.*, connected pores and more or less complex fissures, through which the fluids can move. In the case of metals derived from underlying and surrounding magmas these fissures must penetrate to great depths and horizontal distances. All of this demands more or less violent crumpling or cracking of the earth's crust from time to time, such as arises from its slow adjustment to the changes of volume brought about by the opposing influences of the radiation of original internal heat, and the accumulation of new heat generated by the disintegration of unequally distributed radioactive elements.

METALLOGENETIC EPOCHS.

The processes of concentration of valuable deposits of metallic ores and other minerals in lodes and beds has not been a continuous one throughout the ages. On the contrary, preceding and succeeding long periods of inactivity, there have been well marked epochs during which the concentration

of various minerals has been in active operation in one or other portion of the globe where the optimum conditions for the time prevailed.

For those minerals which are direct segregations within the masses of magmas, these times have been those of the intrusion of the right type of magma towards the surface of the earth and its period of cooling there.

For gold and other mineral deposits in the form of deep seated lodes, the active epochs have been those of intense dynamic changes in the earth's crust, such as appear to be taking place at the present day for example in Japan. Only during such periods, of which four major ones have been well defined in Europe and North America, do the necessary conditions arise for extensive lode formation. These include the crumpling of the earth's crust to great depths, with consequent deep seated fissuring, and the extrusion of magmas into much higher zones in the anticlinoriums. This is followed by the cooling and crystallisation of the magmas, with the emission of heated vapours and liquids, in which their trace elements have been concentrated as in a natural brine.

In Europe and North America the four major epochs which have been recognised, are named as follow: [10]

Age.	Europe.	N. America.
Precambrian	Charnian	Killarnean
Silurian	Caledonian	Taconic
Carboniferous	Hercynian	Appalachian-Ouachita
Tertiary	Alpine	Cascadian-Laramie

Other minor "revolutions," as they have been called, are probably of minor importance in respect of ore formation. In the South-Eastern States of Australia the Silurian revolution of the Northern Hemisphere seems to have been deferred to Devonian times, when it was accompanied by a major formation of gold, tin and other metallic deposits. [11 17] The deposition of gold, which has such a fascination for all of us, is especially associated in many parts of the world with the Precambrian and Tertiary orogenic epochs, of which the former is of exclusive importance in this State. Since then the concentration of gold and other valuable metals has been in abeyance here, except for small surface redistributions from outcrops of Precambrian origin. Important non-metallic minerals have, however, been concentrated during several later epochs.

In the case of economic minerals of sedimentary origin, the controlling principles are still those of mineral provinces and metallogenetic epochs, but they have a different aspect to those controlling the accumulations of minerals produced by subsurface circulation. Furthermore the two factors are inextricably interwoven. The favouring conditions in these cases are purely surface ones, such as the nature of existing rock outcrops, the climate, and conditions of erosion, surface transport and sedimentation, the last involving both the chemical and physical conditions of the basins of accumulation. Throughout the world certain ages have produced similar surface conditions with the resultant concentration of similar valuable beds of minerals.

It is not easy to say which are the most important sedimentary minerals, but the list should include at least salt, coal, petroleum, iron ore, limestone, and potash salts. The formation of coal requires a superabundance of rank vegetation, rapid decay, accumulation of the debris in situ, or at a short

distance, and finally its burial beneath a covering of mud and sand for sufficient periods to mature from humus into coal. The Carboniferous-Permian and the Tertiary Periods produced these requisite conditions in every continent, and the same times seem to have been most favourable for the development and storage of petroleum. On the other hand, a much earlier period, the Archaean, was the most favourable for the growth of large beds of haematitic and magnetic iron ores in such widely separated areas as Scandinavia, India, Western Australia, Brazil and the north-eastern States of America. Deposits of potash salts and boron salts have severely restricted provinces, and epochs of formation. The most important province of the former is in Central Europe and its epoch, the Permian. Of the boron salts the most important provinces are in the western United States, and Tibet, in both cases the genetic epoch being Quaternary. Rock salt is much more widely distributed both in respect of geographical space and geological age. Still more widely distributed is limestone.

APPLICATION TO WESTERN AUSTRALIA.

After briefly outlining the theory of mineral provinces and metallogenetic epochs, it remains to apply them to the area embraced by the boundaries of our own State.

In general it may be stated that with small exceptions the heavy metal deposits in this State are confined to the various stages of the Precambrian, which limits them in respect of both space and time. Only in rare instances do they rise to the Cambrian, Devonian and Lower Carboniferous. In this connection it is to be noted that the Silurian system, which is of such great economic importance in the Eastern States, has not yet been recognised in this State. Most of the deposits here antedate the Nullagine Series, which in the complete absence of fossils, is thought on field evidence to be of Upper Precambrian age. The most important exceptions are the rise of gold through the lowest beds of the Nullagine Series at a few places in the North-West including Nullagine itself, and through supposedly Carboniferous, Permian or Triassic beds at Donnybrook; and the rise of lead and zinc into Devonian beds at Narlarla, and of lead and copper into Nullagine beds in the North-West. Finally there has been the redistribution in shallow alluvial and eluvial ground of such resistant minerals as native gold, cassiterite and tantalite during Pleistocene and Recent times, and the concentration during the same period of brown iron ore and bauxite in primary laterites.

GOLD IN WESTERN AUSTRALIA.

The accompanying map of the State (Plate 1) shows the actual areas where gold has been raised, as distinct from the much wider areas which for administrative purposes have been proclaimed as "goldfields." The gold bearing area has been mapped primarily on the basis of including as probably gold bearing, and plotting as solid black circles, all ground within a radius of 25 miles of every spot where gold has actually been worked. That having been done it is seen that excluding two or three isolated and unimportant areas it is easy to define one major and one minor gold bearing province. The latter occurs in central Kimberley and covers an area perhaps too liberally extended to cover 20,000 square miles. It has yielded less than 0.1 per cent. of the whole gold output of the State. It has not been geologically mapped in detail, but appears to be confined to an area

of Middle Precambrian rocks, possibly associated with some older ones, and to be associated with an intrusion of granite whose outcrop runs N.N.E. between Longs. 127 and 129.

The major gold province stretches from the south coast at Hopetoun to the north coast at Roebourne and covers an area of 250,000 square miles, about one-quarter of the whole State. But for later sediments causing deep embayments on both east and west sides in the northern half, and cutting off a large section on the south-east corner, the actual exposure of gold bearing rocks would be much greater. From the time active gold mining began in 1886 up to the end of 1938 this province has produced nearly 44½ million ounces Troy of fine gold, valued at over £215 million in Australian currency.

Broadly this province may be looked upon as a huge anticlinorium of early and middle Precambrian rocks with a core of granite, the whole having a slight pitch to the north. Later flooding with sediments has considerably modified its primeval boundaries. Though it is not very evident on the map, owing to the liberal boundaries allotted to individual mining areas, all the important gold deposits are confined to the greenstones and sediments forming the flanks of the granite or occurring as infolded "roof-pendents" in it. From the point of view of gold genesis however, the granite core, which includes more than one stage of intrusion, is of the highest importance, since it appears that this is the source from which most if not all of the gold arose. At present it can be traced N.N.W. from the Esperance district across the Eastern railway between Southern Cross and Coolgardie, thence through Central Murchison, at the north end of which it disappears beneath rocks of Mosquito Creek and Nullagine ages, reappearing for a space on the south side of the Hamersley Ranges, and finally showing in central and northern Pilbara.

The time occupied in the accumulation and consolidation of Precambrian rocks has been estimated roughly at 1,000 million years[10], a longer period than has elapsed ever since the youngest of them was formed. To say that gold was mostly deposited in its present position in Western Australia in that era is therefore a very wide and vague limitation of time. Thanks, however, to the researches of our virile Geological Survey, the Geology Department of the University, and a small band of other students of the subject, it is now possible to narrow down this time in several different ways.

Firstly, it is to be noted that except in two very small and unimportant areas near Nullagine in the north and Donnybrook in the south-west, gold has not penetrated upwards into the Upper Precambrian Nullagine Series, or any later series, though the former is heavily invaded by igneous rocks of a basic type, and to a less extent by rhyolites. This sets an upper limit to the main gold depositing epoch, and excludes any correlation with the great Devonian gold producing epoch of the Eastern States.

A lower limit is set by the very widely observed fact that where gold and haematite-jaspilite have been found together, the gold is obviously in every case later than the consolidation of the jaspilite. Evidence not only here, but in such widely separated regions as Canada, Scandinavia and India, place these jaspilites moderately low down in the Lower Precambrian[14, 16].

The numerous auriferous quartz veins in the Middle Precambrian Mosquito Creek-Ashburton Series of metasediments, for example, in the type localities, and at Coodardy and Peak Hill, prove that a considerable proportion of the gold concentration must have occurred long after the first intrusion

of granite. This is indicated by the fact that a large proportion of the beds of this series consists of typical granite debris and derivatives, which could only have accumulated after an extensive granite mass had reached the surface and, having consolidated, been subject to normal erosive agencies.

Other evidence of time is afforded by the relationship of gold to the extensive development of acid pegmatites penetrating the Lower Precambrian, and the much smaller development in the Middle Precambrian. Both of these were associated with granite intrusions, and the presence of them in quartz mica schists of the second series, clearly proves at least two important ages of intrusive granite. In the oldest rocks the auriferous quartz veins usually cut the pegmatite veins, although in Yilgarn there are a number of instances, *e.g.*, at Parkers Range, where the reverse is the case. In several instances acid pegmatite veins are themselves auriferous to an important degree, *e.g.*, at Mt. Palmer and Westonia.

Finally, there are a number of more or less important gold mines, such as Tindals at Coolgardie, Red Hill at Kanowna, and Patricia at Edjudina, which are actually mining porphyry dykes traversed by a network of contemporaneous quartz veinlets, the whole mass being payably auriferous.

It would appear then that the principal gold-producing epoch was associated with an extensive granite intrusion along the axis of the principal province, beginning towards the close of the Lower Precambrian period. It started with the first formation of porphyry dykes and pegmatite veins and continued on till after most, but not all, of these extrusions from the granite magma had ceased to find deep-seated channels reaching upwards towards the surface.

A later epoch of gold deposition of less importance may have been contemporaneous with a second, less extensive, upwelling of granite in late Middle Precambrian time, with a final small dying spurt in early Upper Precambrian time. The former of these, typified by the valuable Coodardy and Peak Hill occurrences, are associated with a very minor formation of acid pegmatite veins and apparently no intrusion of porphyry dykes. On the other hand, the earliest gold veins, such as those of Kalgoorlie, Meekatharra and Wiluna are invariably closely connected with large porphyry dykes. These latter deposits are usually not associated with pegmatite veins, being characteristic of an earlier and hotter period of igneous intrusion, causing extensive metasomatism along the zones of fracture.

Several types of metasomatism, *i.e.*, the chemical alteration of a rock mass, are evident as the result of the impregnation of the older rocks with gold, and these shed considerable light upon the physical and chemical conditions under which the gold was introduced and deposited.

Immense pressures are indicated in many cases by the forcing of the gold-bearing fluid along microscopic fracture planes of such dense rocks as amphibolites, hornblende schist and chlorite schist. It has even been capable of penetrating between individual crystals of the densest rocks, producing metasomatic replacements with gold deposition at a distance from any even microscopically visible fissure. Comparatively high pressures and temperatures are also indicated by the formation of such secondary minerals as tourmaline and scheelite.

Of chemical changes accompanying gold deposition there is widespread evidence of (1) sulphidation, (2) silicification, (3) carbonation, (4) micacisation, (5) chloritisation. These alterations are not mutually exclusive, but

in many instances concurrent. From the nature of things, the component minerals of greenstones are more susceptible to chemical change than those of acid igneous and siliceous sedimentary rocks. The alteration of old dykes, lava flows and tuffs derived from gabbro and peridotite is much more severe in the vicinity of gold veins than that of granites, gneisses, slates and mica schists. Incidentally, this severe alteration of greenstones by auriferous fluids was necessarily accompanied by equally extensive alterations in those fluids themselves, and so favoured the local deposition of gold from them.

Dealing briefly with the various types of metasomatic change, *sulphidation* involved the formation of pyrite, arsenopyrite, and less often pyrrhotite through interaction of amphibole, chlorite, magnetite, haematite and other iron-bearing minerals with sulphur and arsenic bearing ions in the fluids. As there is a mass of evidence pointing in very many cases, notably at Kalgoorlie, Wiluna and Mt. Magnet to the introduction of gold as the sulphaurate ion $(AuS_2)^-$, the tendency of the iron-bearing minerals particularly chlorite and magnetite to combine with the sulphur of this ion must have been a major cause of the precipitation of gold in or alongside the sulphide minerals. Most noteworthy and significant in Murchison is the enrichment of gold in veins where they cross magnetite jaspilite bands, with simultaneous conversion of magnetite into pyrite.

Silicification.—In addition to the almost universal deposition of quartz with gold in open fissures to form the typical reefs, there are many instances of the impregnation of auriferous crush zones with chalcedony in the form of metasomatic replacements of the original minerals, *e.g.*, at Marble Bar and Kalgoorlie.

Carbonation is a widespread phenomenon in gold deposits in greenstones, considerable proportions of calcite, ankerite and occasionally magnesite, occurring as replacements of labradorite, amphibole, chlorite and antigorite in the veins of Warrawoona, Wiluna, Meekatharra, Reedy, Leonora and Kalgoorlie, to mention only a few typical examples.

Micacisation.—The development of secondary sericite along the lode channels, often in rocks originally very deficient in potash, indicates the large quantity of potash in solution in the auriferous fluids. It is frequently associated with carbonation, as in the six localities cited in the last paragraph, but in some places, *e.g.*, Burbanks, has been found without carbonation. In the latter case, as well as at Menzies, biotite is formed rather than muscovite, a result to be expected when the original iron and magnesia are not converted into carbonates.

Chloritisation appears in many instances to have preceded and accompanied gold deposition, pyroxenes and amphiboles being converted *in situ* into corresponding chlorites, and small nests and films of chlorite being formed in auriferous quartz veins.

At this stage it is pertinent to consider the form in which gold has been introduced into its present position, a matter briefly referred to above under "sulphidation." Most authors dealing with this and other regions consider that gold was brought in from the granite magma in acid or neutral solutions of gold chloride, and instance its precipitation, *e.g.*, in Victoria, in proximity to graphitic zones of rock. In Western Australia graphitic rocks are widespread in the rock complex within gold mining areas, but in no instance of which I am aware has any gold been found either impregnat-

ing the graphite rocks, or concentrated at contacts with them. On the contrary, iron oxides and silicates, which would be expected to upset the equilibrium of a sulphide solution of gold are invariably, one or the other or both, present in abundance. My own theory is that gold was introduced into its present situation in the form of an alkaline or neutral solution of potassium and sulphaurate ions (K-AuS_2) in mutual equilibrium. This theory was briefly outlined by the author in 1912 in a study of the gold ores of Kalgoorlie[7]. Twenty-seven years' further study has confirmed it completely. The chief arguments in favour of it are: (1) gold is soluble in potassium sulphide solution to form potassium sulphaurate, (2) the equilibrium of this solution is upset, and gold precipitated, not by graphite, but by oxidising agents, and by compounds of metals, such as iron and copper, which combine readily with sulphur to form stable compounds; (3) gold is actually found in association with oxygen-bearing iron compounds of the original rock which have been in part sulphidised during ore deposition, particularly haematite and magnetite to pyrite, and ferruginous chlorite to a bleached mixture of pyrite or pyrrhotite, and a magnesian chlorite or sericite; (4) in all the typical metasomatic greenstone lodes there is a marked increase in potash content, with a development of sericite, or occasionally biotite, neither mineral a constituent of the original rock. This theory furthermore explains the simultaneous occurrence of tellurides and arsenopyrite in some cases, since the ion AsS_3 would certainly be stable and unstable under the same conditions as AuS_2, and presumably also the ion TeS_2.

COPPER.

In a comparative sense no really large copper concentration has yet been found in any part of the State, only four deposits being of any serious importance. The total production of ore has been 270,000 tons, valued at a little under £2,000,000. More than one-half of this was produced between 1901 and 1920, since when the industry has waned considerably.

Although copper, like gold, has been found practically entirely in Precambrian rocks, and by far the greater part in association with the same vast anticlinorium stretching from Pilbara to Phillips River, there are important differences in the distribution of the two metals both in space and time. As the latter affects the former, it will be dealt with first.

According to field authorities* there is very little doubt that many copper ore occurrences in the northern part of the main province, *e.g.*, south of Roebourne and throughout the Ashburton Valley, are in Nullagine beds of Upper Precambrian Age. Rocks of this age have not been defined with certainty in the lower part of the province, so that the age of the lodes traversing the Lower and Middle Precambrian beds in that region cannot be fixed within close limits.

It is to be noted that whilst at Ravensthorpe, Roebourne, and some parts of the Ashburton Valley the same veins yield important amounts of both copper and gold, elsewhere copper ores are very poor in gold. Again, the latter metal for the most part does not extend upward into the Upper Precambrian, which points to the introducion of copper beginning when that of gold was waning, and continuing for a long period after gold had ceased to be concentrated in veins.

* T. Blatchford, H. A. Ellis, K. J. Finucane, *et alia.*

There is good reason to believe that copper is derived from doleritic, and not from granitic magma, hence its association with the same central granite upheavals as gold is due not to the granite being the source of the metal, but to the extensive fissuring and dislocation accompanying its upthrust. These dynamic changes permitted the intrusion of dolerite magma and the subsequent derivation of copper ores from it. It is known in fact that extensive dolerite intrusions occurred in the Nullagine Period, and this must be considered the main copper producing epoch in the State's history.

Turning to the map (Plate 2) illustrating the distribution of copper, where again actual mines and workable deposits are indicated by solid black circles, we note first small isolated areas of copper-bearing rocks in East and West Kimberley. The main copper province, however, overlaps the main gold province as regards three-quarters of its area, but differs to an important degree in not extending so far to the east between Lats. 27 and 31, and on the other hand in having a wide extension towards the west in the same latitudes. In detail it is to be noted that there have been much fewer productive centres of copper than of gold, and that these tend to be distributed round the periphery of the province. In fact, the four most important producers of copper, Whim Creek, Murrin, Ravensthorpe and Northampton, are on the extreme borders of the province. So, too, are the less important centres at the head, and near the mouth, of the Ashburton River.

We are led then to the important generalisation that new copper deposits of value are most likely to be found round the periphery of the major province as outlined.

LEAD AND SILVER.

A glance at the map (Plate 3) which illustrates the lead occurrences in the State shows an entirely different distribution to that of gold and copper. This is of course viewing the occurrences from an economic standpoint, and taking into account that it takes several hundredweight of lead to have the same value as a single ounce of gold. As a matter of fact lead in proportions of the same order as that of gold (*i.e.*, in pennyweights to the ton), is widespread in the auriferous veins of the main gold province, and are looked upon by miners in many places as indicative of payable gold ore. These amounts are not economically recoverable, and are therefore negligible for our purpose.

Lead in commercially valuable quantities is so far known to occur only in three small provinces. The largest in point of area, though not in point of production, is one covering about 50,000 square miles in the Pilbara-Ashburton region. This includes the two important centres of Braeside and Uaroo. The next largest, but least productive, is in East Kimberley, and covers about 15,000 square miles. The smallest, but by far the most valuable up to the present, is the Northampton area covering only about 1,000 square miles.

Except for the unique Narlarla lead-zinc segregation veins in Devonian limestone (in West Kimberley) the lead producing epoch appears to have been co-extensive with, to slightly later than, that of copper, veins containing the two metals, either separately, or in conjunction, being often associated. The order gold-copper-lead represents the upwards sequence in time of concentration of the three metals, the copper epoch overlapping partly those of both other metals. Lead veins are mainly found in Middle and

Upper Precambrian rocks. In the Northampton area, where most detailed investigation has been done, galena and chalcopyrite are frequently found together in quartz veins and impregnations in garnetiferous paragneiss. They are closely associated with acid pegmatite veins and dolerite dykes.

In the Northampton district only traces of silver occur with the lead. In the Pilbara-Ashburton province on the other hand important amounts of silver accompany the lead, and it is this area which has yielded practically all the silver-lead ore which appears in the official statistics. Many of the East Kimberley lead ores are also rich in silver. All the "metallic silver," as distinct from "silver-lead," recorded in the statistics, which constitutes quite three-quarters of the total output of the metal, has been derived from the comparatively insignificant amounts alloyed with gold in our gold ores.

The statistics to the end of 1938 are approximately as follow:

Lead concentrates, 115,000 tons	£A. 1,700,000
Silver, 5½ million ounces	700,000

TIN, TANTALUM AND NIOBIUM.

The distribution of ores of these three metals is coincident, since they are genetically closely related. It is recognised however that the relative proportions of the metals may so vary from place to place that an area of value for its tin ores may be of little value for its tantalum or niobium ores, and vice versa. In some districts too tantalum predominates over niobium, in others the reverse condition prevails. As concentrates rich in tantalum have averaged £700 a ton in value, those rich in tin £105 a ton, and those rich in niobium only £70 a ton, this variation is of considerable economic importance.

These metals are derived in Western Australia from intrusive granites, usually those in which soda predominates over potash. They are confined to the pegmatite veins (and their detritus) which have developed round the margins of the granites and the greenstones into which they are so often intrusive. They appear to have been introduced into the veins as vapours or solutions of the corresponding metallic fluorides, whose stability was upset by the formation of lepidolite or other micas, topaz, and apatite.

Only one determination has been made of the age of these veins. This was of the most important tantalum bearing vein at Wodgina, which was found, by examination of a certain uranium mineral, to be 1,260 million years old, thus placing its formation low down in the Lower Precambrian era, the earliest stage of which has been placed at about 1,500 million years ago. Deposits in other parts of the State appear to be either of similar age or of later age up to the commencement of the upper Precambrian era, rocks of which age do not contain tin or tantalum veins in this State.

In Kimberley there are three or four small isolated occurrences of tin, in one of which it is associated with tungsten (Clara Hill), in the other with tantalum and niobium (Mt. Dockrell). These have been combined in a province covering about 15,000 square miles of Middle Precambrian rocks. (See Plate 4.)

The most important province is in Pilbara, and covers also about 15,000 square miles. This includes Wodgina, Strelley, Moolyella, and a number of smaller mining centres in which tin, tantalum and niobium occur together in varying proportions, mostly in Lower Precambrian rocks.

Another province occurs in the South West covering about 10,000 square miles. Near its southern end is Greenbushes, a very important source of tin, and a minor one of tantalum.

Three other provinces of little economic importance so far are shown on the map, one between the Ashburton and Gascoyne Rivers, another in the Murchison, and a third in the Coolgardie region.

The total production of tin and tantalum ores to the end of 1938 is:

Tin concentrate	15,700 tons —	value £1,650,000
Tantalum and niobium concentrate	267 tons —	value £180,000

IRON.

The definition of iron provinces in the State is not yet possible for several reasons. Iron minerals of one kind and another are universally distributed throughout the land, and until a decision has been reached as to what grade of iron ore is economically workable, it is impossible to draw boundaries to areas containing them. Furthermore only a very small number of our jaspilite haematite-magnetite lodes, and lateritic brown ore beds, have been sampled and assayed to determine their grade. On the accompanying map (Plate 5) an attempt has been made to plot the more important deposits of which any accurate data are available. It is necessarily very incomplete.

The age is not so difficult to determine. The jaspilite ores, containing haematite and magnetite, occur low down in the Lower Precambrian, and are probably contemporaneous with the enclosing rocks. A certain decision on this point awaits the solution of an identical problem in every Precambrian shield throughout the world. Their distribution is co-extensive with the Lower Precambrian volcanic greenstones, but a large proportion of them are too poor in iron, and too rich in silica, to be looked upon as commercial ores.

Of different age is the largest known iron ore body in the State, viz. that at Yampi. This is a true sedimentary bed, or series of beds, composed of rolled grains of magnetite more or less completely altered into haematite, forming part of a series of Middle Precambrian sediments, which defines its age.

Of a quite different type and origin are certain iron sulphide lodes, mainly pyrite and pyrrhotite with some magnetite and iron bearing silicates, whose oxidised outcrops contain important quantities of brown iron ore. These appear to occur in Middle Precambrian rocks, and to be of somewhat later age than the enclosing rocks. At one place, Parker's Range, they are accompanied by extensive veins of iron carbonate.

Finally there are the sporadically distributed patches of high grade brown ore in the extensive bauxite duricrusts, which are of Post-Tertiary age, and possibly still growing.

The only production of iron ore in the State has been that required for a flux in lead and copper smelting, which is thought to have been about 60,000 tons. In addition about 75,000 tons of pyritic ore have been used in the manufacture of sulphuric acid.

MINOR METALS AND METALLOIDS.

Zinc is practically unknown in commercially important quantities in the State, only £5,000 worth of concentrates having been produced. Moderate amounts however occur with lead at Northampton in probable Middle Precambrian rocks, and with copper at Croydon and Murrin in Lower Precambrians. One small zinc lead deposit at Narlarla in Kimberley occurs in Devonian limestones. This is one of the extremely few Postcambrian ore deposits known in the State.

Antimony is confined to the Lower and Middle Precambrian series of a few isolated centres, only one-third of which have produced commercial parcels of ore. Altogether these have contained about 1,000 tons of the metal valued at £15,000. Except for a few unimportant associations with lead, the antimony has been found to be accompanied by gold in rocks of either Lower or Middle Precambrian age. The presumption is that the time of introduction into its present position was in each case the same as that of the associated lead or gold. When the distribution of antimony is plotted on the map, the occurrences are found to fall into two provinces, one of about 45,000 square miles in the North-West Region, the second of about 60,000 in the Central Region.

Arsenic is rapidly becoming an important product of the State, about 22,000 tons of white arsenic, valued at £350,000 having been produced to the end of 1938. This has all been obtained from Lower Precambrian rocks, where it has been associated with gold, usually in the form of arsenopyrite. A little also occurs as cobaltite, tennantite and enargite. These minerals have all been formed at approximately the same time as the older gold deposits in which they occur. Insignificant amounts also occur with tin ores, in one case in Middle Precambrian rocks. The main genetic epoch, or epochs, was then from the later part of the Lower Precambrian to some time in the Middle Precambrian.

Omitting a few isolated areas unlikely ever to yield commercial quantities of arsenic, the known occurrences may be grouped into the two provinces shown on the accompanying map. (Plate 6.) The central one is the more important and embraces about 150,000 square miles of the central Precambrian shield. The smaller one in the North-West has not yet yielded any commercial supplies, but may do so in the near future.

Tungsten is known only in a few small isolated places stretching from West Kimberley to Norseman, of which the most important appears to be Comet Vale. In several places it occurs without other metallic associates, but more often it is found with gold, with which it appears to be contemporaneous, in rare instances it occurs with molybdenum or tin. The latest rocks it occurs in are Middle Precambrian, and its time of formation corresponds probably with both early and late gold epochs. The production to date is insignificant.

Chromium in the form of chromite so far is known in commercial quantities only in the small area at the east end of the Hamersley Range, where it is contemporaneous with the Lower Precambrian serpentine in which it occurs as segregations. Small quantities of chromite, fuchsite, and miloschite are however found in serpentines of several probable ages in many other parts of the State, and in any of these commercial supplies may one day be located.

Manganese has been worked on a very small scale in Murchison (Horseshoe) and on the South Coast (Ravensthorpe, Eyre Range). There are no data on which to base a map of its distribution, or form an opinion as to its age of formation.

EARTHY MINERALS.

The theory of mineral provinces and metallogenetic epochs may profitably be applied to certain non metallic minerals, *e.g.*, diamond and asbestos. The latter affords the best example so far as this State is concerned.

Asbestos is not the name of a single mineral species, but of a group of silicate minerals, conveniently associated in commerce because they all possess the same finely fibrous structure, with tough and flexible fibres, and can be applied to similar uses. In this State there are three main species of economic value, viz., chrysotile (a highly hydrous silicate of magnesium), anthophyllite (a slightly hydrous silicate of magnesium) and crocidolite (hydrous silicate of sodium and iron). The occurrences of these three minerals are now sufficiently well known for us to be able to allot to each a definite mineral province and a probable age of formation. (See Plate 7.) Crocidolite for instance is confined to the Upper Precambrian (Nullagine) rocks of the Hamersley Range.

Several other earthy minerals of economic importance such as coal, graphite and glauconite could be dealt with in the same way. The distribution of the first, which is of such great importance, has been plotted on the same map as that of asbestos. It is confined to beds of Permian and Miocene age, and to the South Western region of the State.

CONCLUSION.

What is the practical application of all this observation and deduction?

I think it will be realised that from the administrative standpoint in the planning of all new railways, main roads and water supply schemes not only the existing population, but the probable future trend and intensification of population must be considered. There is a considerable amount of data regarding rainfall, soils, crop yields and pastures available to predict the future trend of agriculture. Timber areas too are closely defined. But it has appeared to me that the data regarding mineral resources had not previously been correlated and plotted in a way that would enable present and future Governments to consider the directions in which the mining industry is likely to continue and to expand. Some attempt has been made here to remedy that defect.

Manufacturers too are, and always will be, in need of a guide as to where their factories should be situated in order to be within economic reach of their raw materials.

Finally mining is a business like any other mainly pursued to afford an adequate living to a large number of people, and a possible fortune to the lucky few. I do not think it is in the interests of either the individual or the country at large that the money and energy of any section of the mining community should be expended in directions which are either uneconomical or predoomed to utter failure. I am in hopes that my definition of the distribution of the State's economic minerals in space and time will not only guide the prospector to continue his search within the favourable limits, but will also serve to prevent the waste of valuable capital, both of wealth and of energy.

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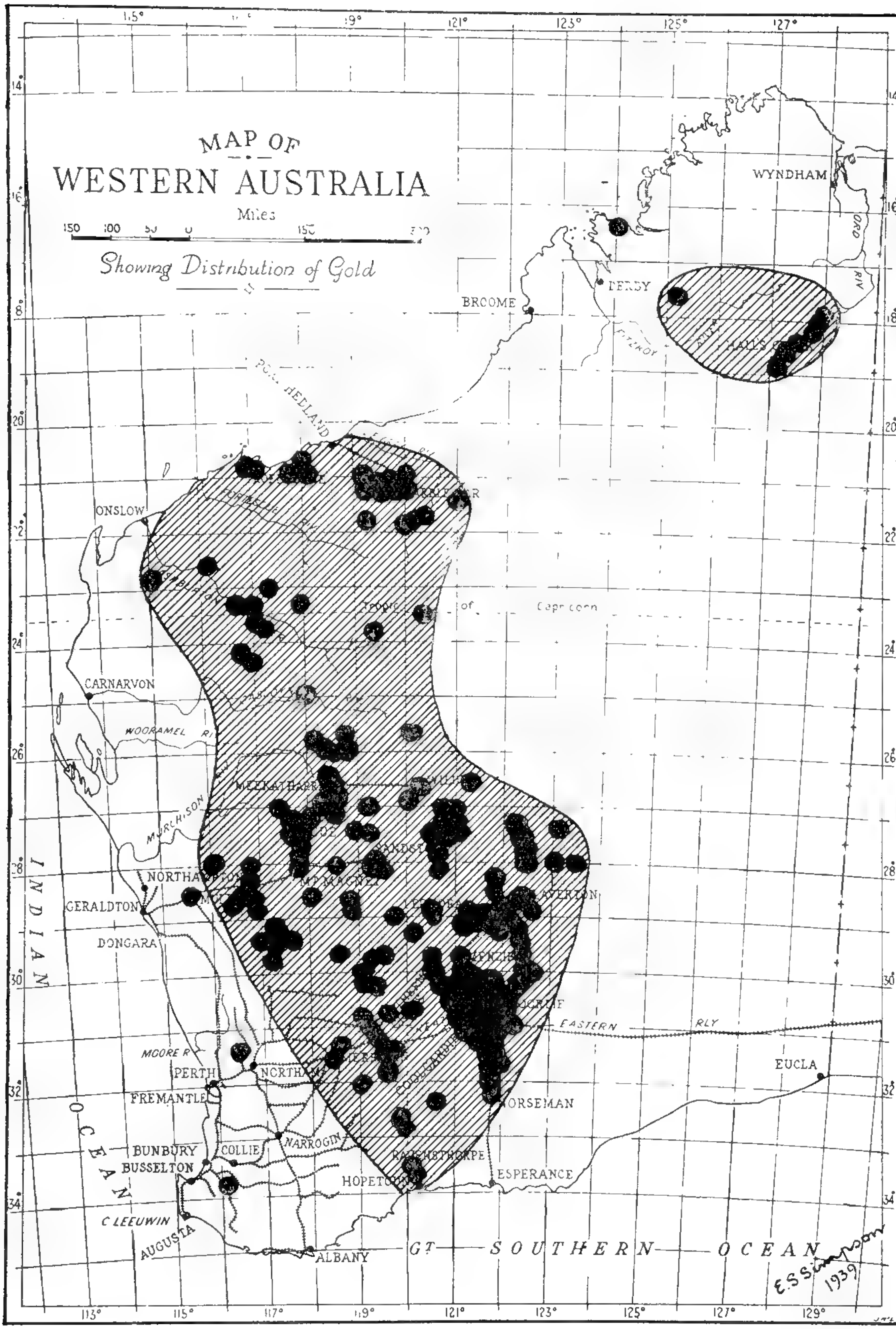
MAP OF
WESTERN AUSTRALIA
Miles
Showing Distribution of Gold
WYNDHAM
BROOME
DERBY
ONSLOW
CARNARVON
GERALDTON
DONGARA
PERTH
FREMANTLE
BUNBURY
BUSSELTON
COLLIE
NARROGIN
C LEEUWIN
AUGUSTA
ALBANY
HOPETOUN
ESPERANCE
NORSEMAN
EUCLA
EASTERN RLY
INDIAN OCEAN
GT SOUTHERN OCEAN
E.S. Simpson 1939
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PLATE I.

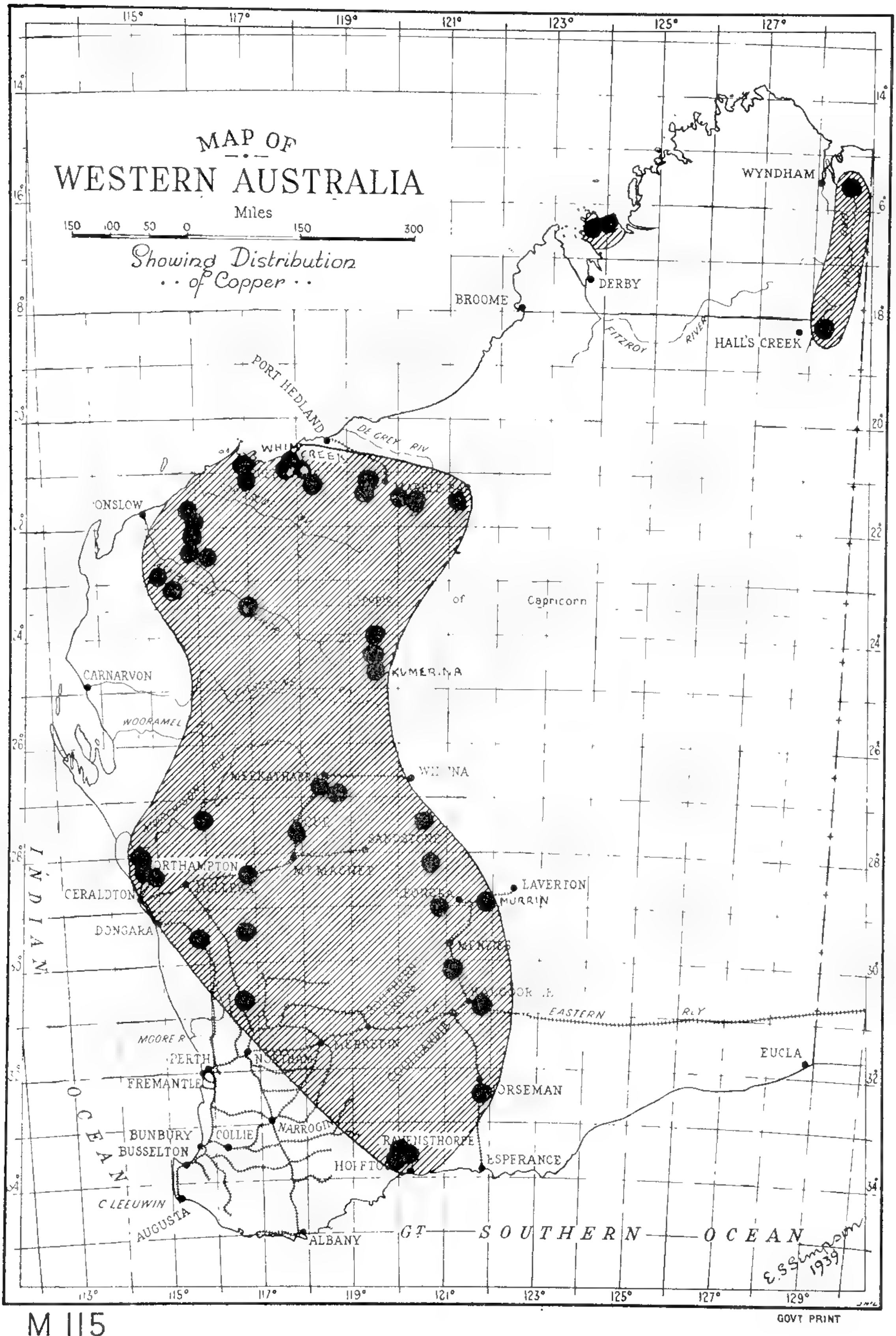
MAP OF
WESTERN AUSTRALIA
Miles
150 100 50 0 150 300
Showing Distribution of Copper
WYNDHAM
DERBY
BROOME
FITZROY RIVER
HALL'S CREEK
PORT HEDLAND
DE GREY RIV
ONSLOW
of Capricorn
CARNARVON
WOORAMEL
KUMERINA
WILUNA
LAVERTON
MURRIN
NORTHAMPTON
GERALDTON
DONGARA
Mt MAGNET
EASTERN RLY
EUCLA
MOORE R
PERTH
FREMANTLE
NORSEMAN
NARROGIN
BUNBURY
COLLIE
BUSSELTON
RAVENSTHORPE
ESPERANCE
HOPETOUN
C LEEUWIN
AUGUSTA
ALBANY
INDIAN OCEAN
GT SOUTHERN OCEAN
E. S. Simpson 1939
113° 115° 117° 119° 121° 123° 125° 127° 129°
14° 16° 18° 20° 22° 24° 26° 28° 30° 32° 34°
M 115
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PLATE II.

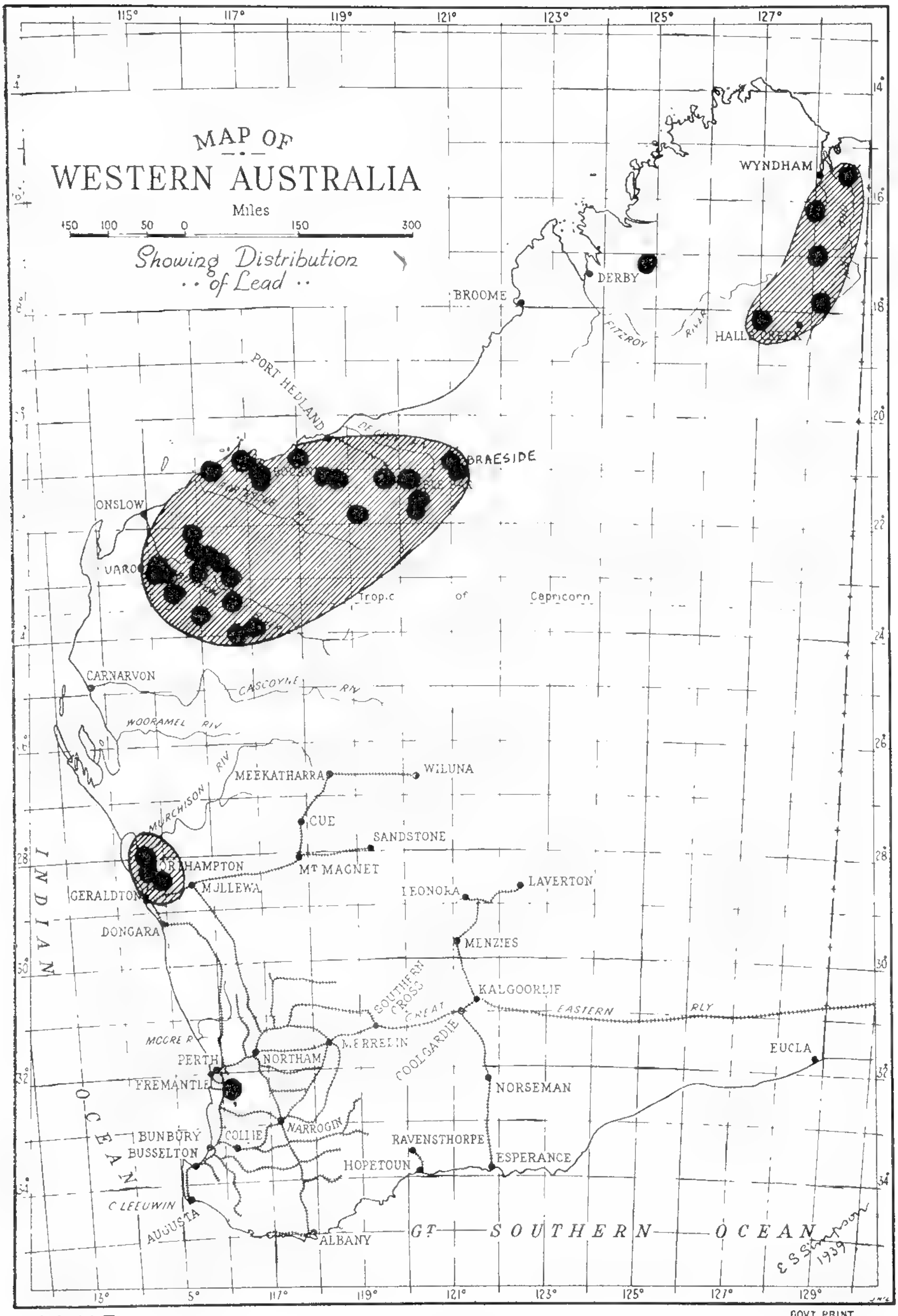

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PLATE III.

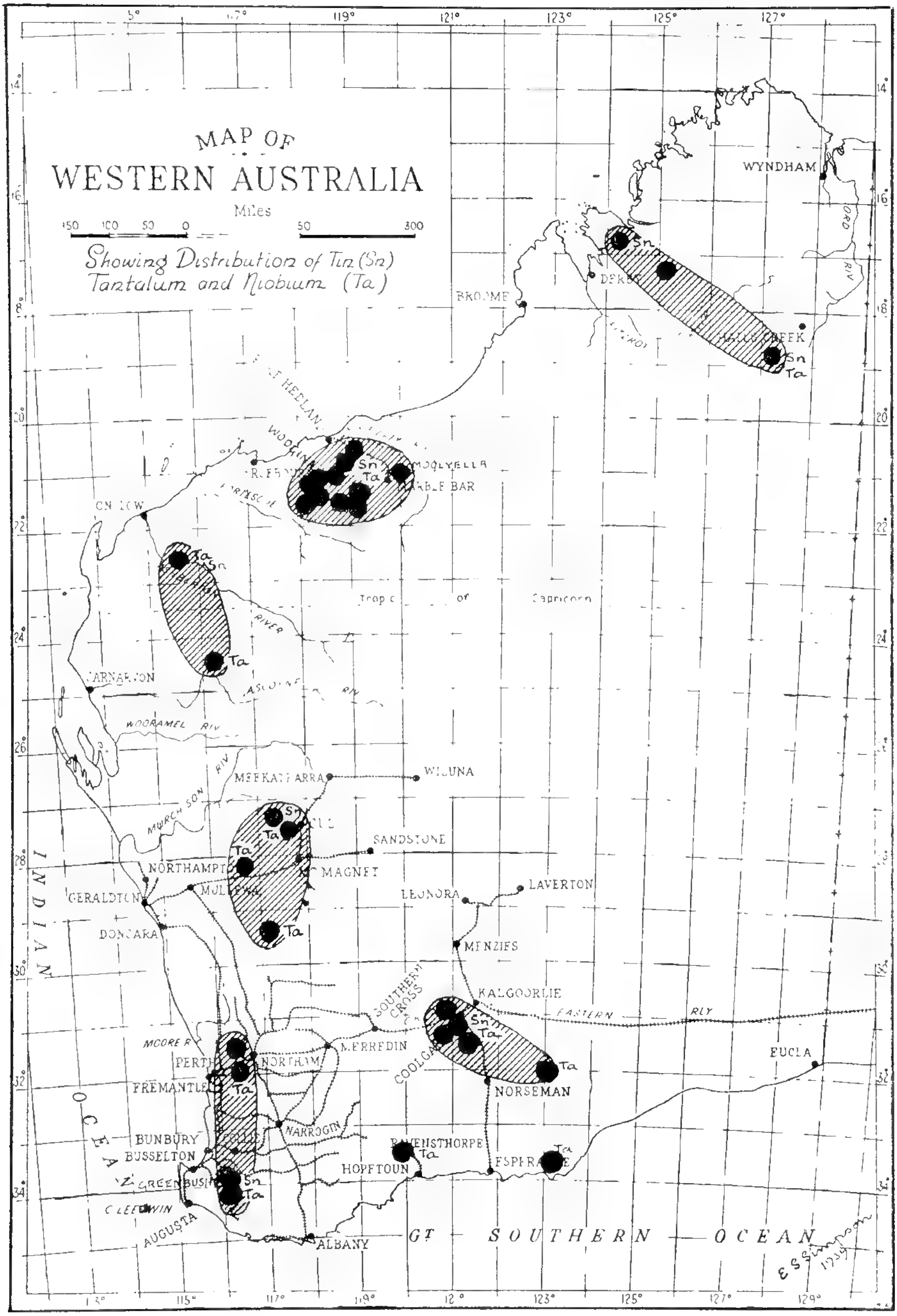

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PLATE IV.

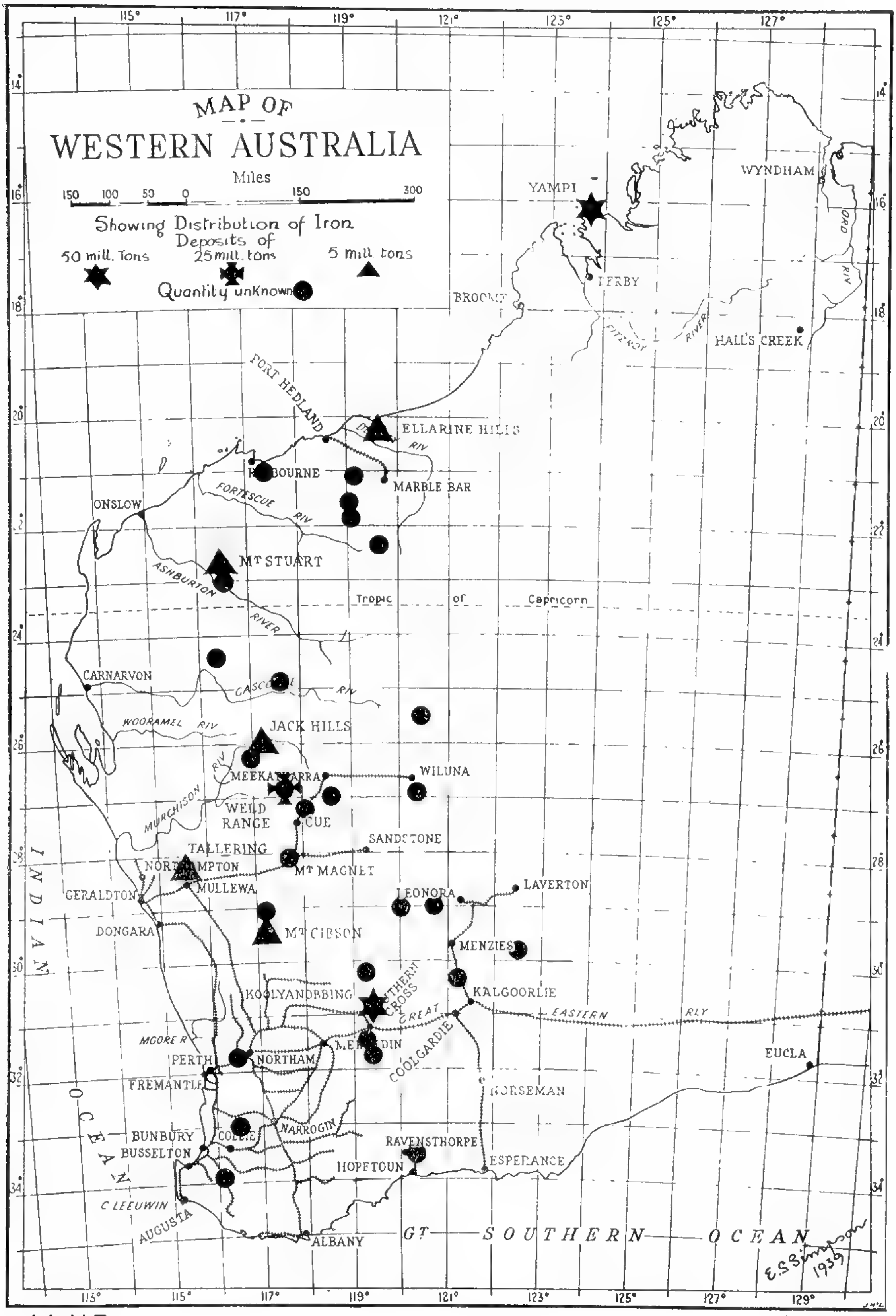
MAP OF
WESTERN AUSTRALIA
Miles
150 100 50 0 150 300
Showing Distribution of Iron Deposits of
50 mill. Tons
25 mill. tons
5 mill tons
Quantity unknown
WYNDHAM
YAMPI
DERBY
BROOME
FITZROY RIVER
HALL'S CREEK
ORD RIV
PORT HEDLAND
ELLARINE HILLS
MARBLE BAR
ROEBOURNE
FORTESCUE RIV
ONSLOW
MT STUART
ASHBURTON RIVER
Tropic of Capricorn
CARNARVON
GASCOYNE RIV
WOORAMEL RIV
JACK HILLS
MURCHISON RIV
MEEKATHARRA
WILUNA
WELD RANGE
CUE
SANDSTONE
TALLERING
NORTHAMPTON
MT MAGNET
GERALDTON
MULLEWA
LEONORA
LAVERTON
DONGARA
MT GIBSON
MENZIES
INDIAN OCEAN
KOOLYANOBBING
SOUTHERN CROSS
KALGOORLIE
GREAT EASTERN RLY
MOORE R
PERTH
NORTHAM
MERREDIN
COOLGARDIE
EUCLA
FREMANTLE
NORSEMAN
BUNBURY
COLLIE
NARROGIN
BUSSELTON
RAVENSTHORPE
HOPETOUN
ESPERANCE
C LEEUWIN
AUGUSTA
ALBANY
GT SOUTHERN OCEAN
E.S. Simpson 1939
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PLATE V.

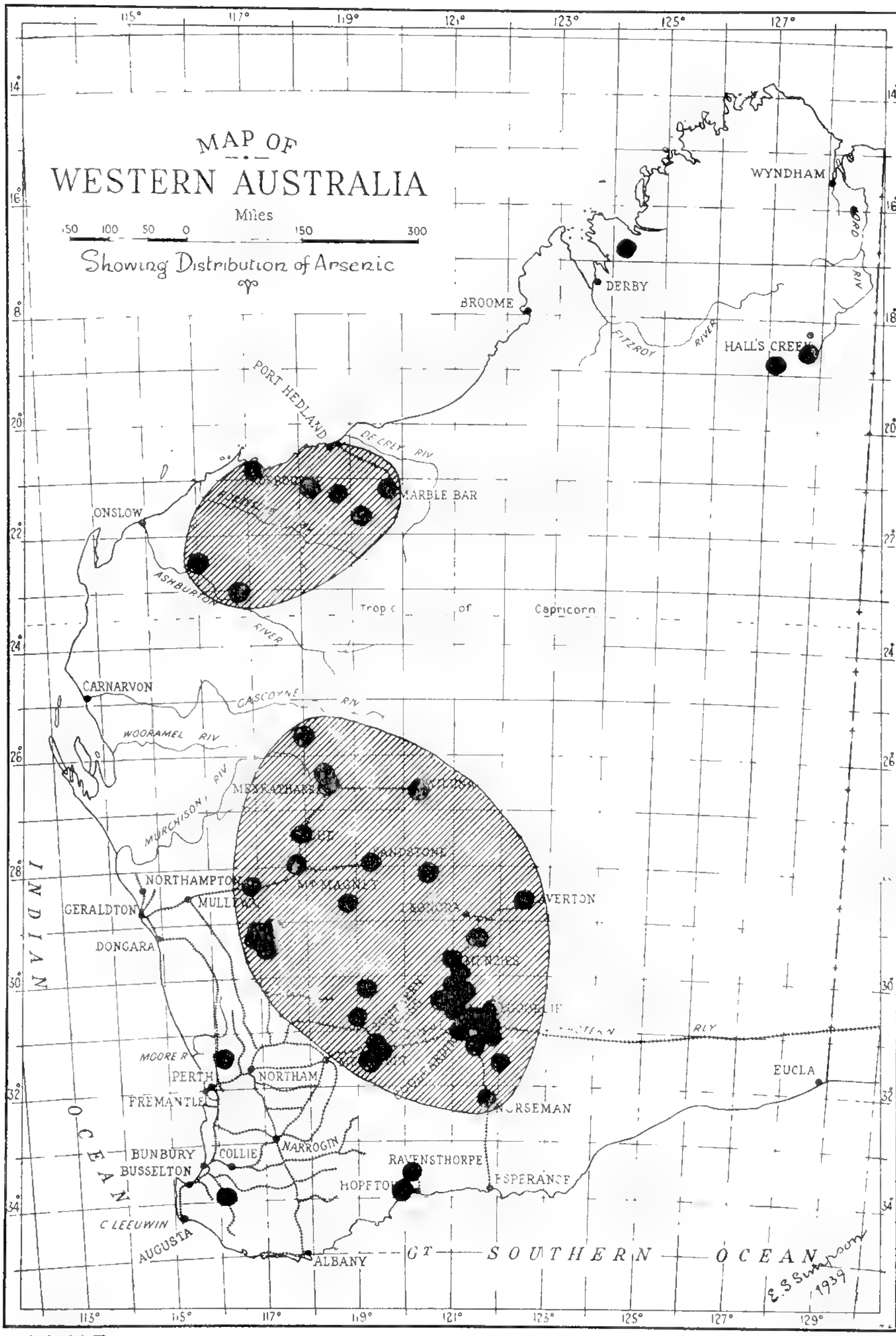

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PLATE VI.

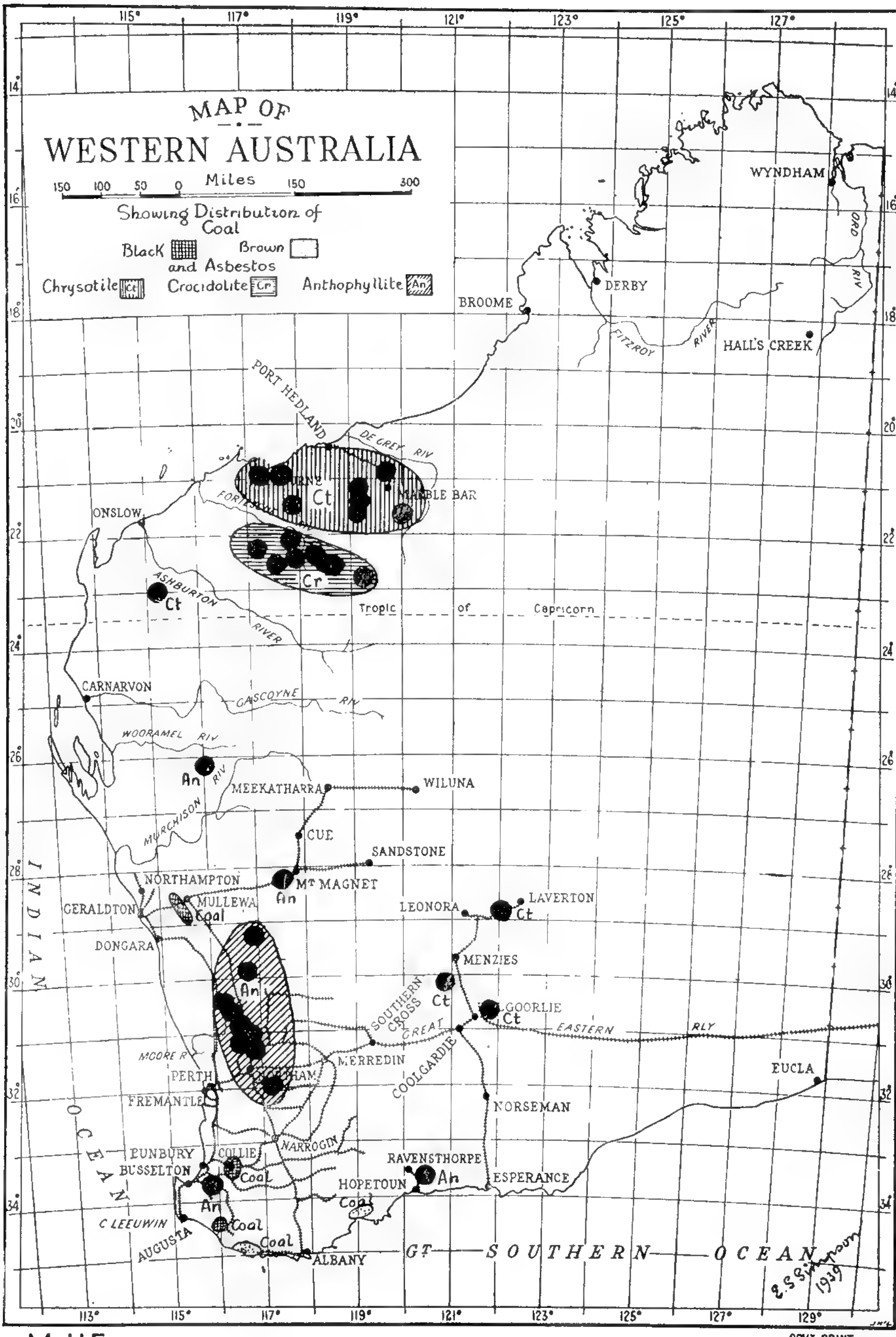

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PLATE VII.

GENERAL INDEX.

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